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Integrated Management of Rodents and Other Wildlife in Campgrounds

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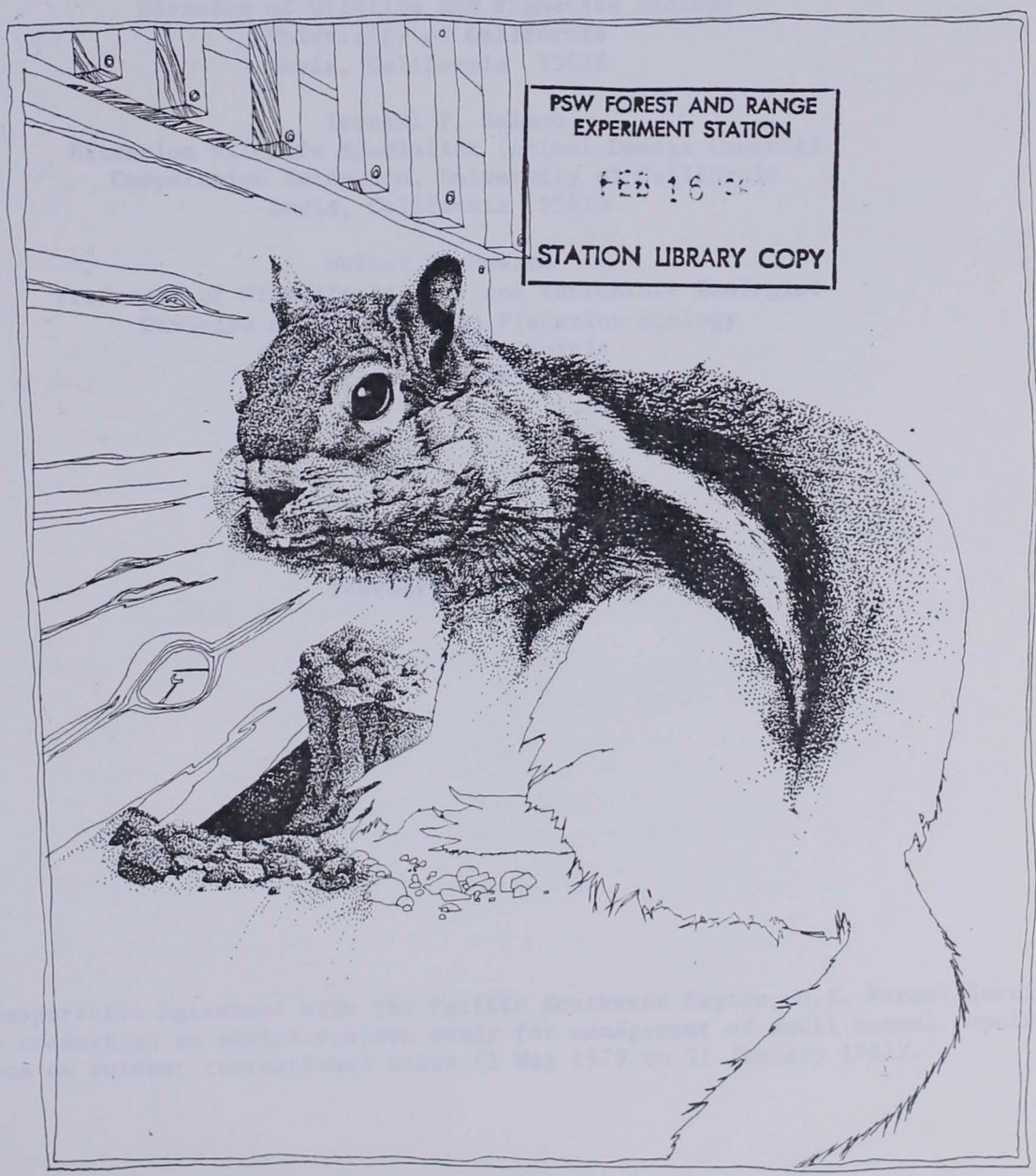

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INTEGRATED MANAGEMENT OF RODENTS AND OTHER WILDLIFE IN CAMPGROUNDS*

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I. ABSTRACT

Unnatural high densities of rodents often develop as a result of the habitat modifications produced when campgrounds are established. The construction of a campground provides extra water, food (especially from people), and improved burrowing sites under concrete slabs, paved roads and culverts, road embankments, and when rock traffic barriers are only slightly buried. When rodent densities are high, the stage may be set for an epizootic of plague or other disease.

This paper discusses the key species of rodents involved, the types of problems they and a few other kinds of wildlife create in campgrounds, reviews the chief diseases that may be involved (primarily plague), and what can be done to correct and prevent these wildlife/campground conflicts.

The integrated management plan proposed includes sanitation, habitat modification, changes in design of facilities, and other suggestions. Methods are provided for simple means of determining when too many rodents are present, and what to do from the public health point of view when dead rodents are discovered. The various ways of controlling rodent populations are presented, and a general overview of what is done to control the ectoparasites of rodents is discussed.

II. INTRODUCTION

There has long been a need for management information relative to rodent-borne diseases transmittable to humans (zoonoses) and methods for preventing habitat and structural rodent damage within camping facilities. With more and more people using campground facilities and with the recent increase in the incidence of plague, this need has grown. The presence of plague in campgrounds has in a number of instances necessitated the closing of the campgrounds, forcing the campers to leave, thus disrupting their planned vacations. Campers counting on the use of those facilities must change their plans as alternate camping sites are seldom available. This is not only upsetting to the campers, but costly. Natural resources are not being used for their intended purpose and a loss of revenue occurs; yet the expenses for maintaining the facilities continues. The closure of large campgrounds early in the vacation season may also have a dramatically adverse impact on nearby communities which rely on vacationers and campers to support the local economy.

Present biological and management knowledge, if properly used, can minimize potential disease hazards to humans and substantially reduce rodent-caused damage to the landscape and the structural components of campgrounds. Evidence suggests that proper management of the rodents and/or their ecto-parasites would nearly eliminate the need for campground closures, without placing any greater risk on those who use or work in the campgrounds.

It is apparent that existing knowledge needs to be brought together into an integrated rodent-management plan which also takes into consideration other wildlife species. From a public health point of view, there appears a strong positive correlation between dense rodent populations of such species as chip-munks, ground squirrels, and wood rats and the potential for human plague

cases. Rodent ectoparasite control by itself has not prevented plague outbreaks in these highly susceptible rodents; hence rodent control or a combination of both rodent control and ectoparasite control is called for. Methods for the control of rodents are quite diverse, leaving a number of options open; however, methods of rodent-ectoparasite control are more limited.

Due to the lack of prepared guidelines and assembled management information as to the best steps to follow to prevent or resolve these campground problems, this cooperative agreement with the U.S. Forest Service, Pacific Southwest Region, was undertaken to:

1. Analyze rodent problems in Forest Service recreational areas that relate to public health and the depredation of these sites and facilities.

2. Establish guidelines or parameters for maintaining optimal, i.e., not excessive, densities of native rodents such as wood rats, chipmunks, and ground squirrels in and adjacent to recreational sites.

3. Assure the appropriateness of the various recommended methods of managing rodents and insect vectors in campgrounds.

4. Formulate emergency plans for use when rodent-borne diseases become a threat to humans.

5. Prepare an overall integrated pest management (IPM) plan for use in campgrounds and other recreational areas.

The goal has been to assemble and present this information in a manner which will also enable the campground managers or rangers to have a ready reference or source document which can be used to:

1. Assist in managing the campgrounds with a minimum of health risks to the users and with a minimum of rodent-caused damage to the facilities, yet not sacrifice the quality of camping.

2. Assist in preparing environmental analyses when needed.

3. Provide campground rangers with a source of ready information to discuss the wildlife and associated problems intelligently with the public.

This volume, as intended, places emphasis on rodents and health and related structural damage problems. Certain other species of wildlife such as bats, birds, rabbits, and moles are mentioned, because they are also sometimes implicated in certain diseases transmissible to man, and some are involved also in structural damage problems; but their management is either not discussed or only briefly so. The augmentation of this volume with the use of the Region 5-6 Forest Service "Animal Damage Control Handbook" will be especially valuable.

Two documents exist which outline present Forest Service Regional policy in regard to plague suppression and associated problems. The first is "Title 2300 - Recreation Management" from the Forest Service Regional Manual (FSM 2331.32--4-6), which outlines current policy regarding plague suppression. The second (Region Five Supplement to FSM 2141.22) is the Forest Service's Memorandum of Understanding with the California Department of Health (now the Department of Health Services). The above two documents remain in effect and nothing in this volume is intended to conflict with existing policy, but rather to complement them by providing resource information.

We greatly appreciate the generous inputs, assistance, and courtesies received from many personnel of the Forest Service and the California Department of Public Health. It is these contacts which made this report possible. Much of the literature review used in assembling this volume was done by graduate student Lori Hamburger LaVine and former graduate student Paul S. Miller. Ms. Nona Smith drew all of the illustrations except Figure 3.

III. CAMPGROUND WILDLIFE

A. Recreational Value and Biological Benefits

No one questions the intrinsic value of wildlife; even a bold ground squirrel can greatly enhance one's outdoor experience at a Forest Service campground. The temptation for campers to feed rodents, birds, deer, bears, and, more recently, coyotes, is almost overwhelming in many instances, even though it is both biologically and ecologically undesirable. Today such wildlife are utilized in a "nonconsumptive" way, i.e., by capitalizing on the aesthetic value of observing them in nature or of photographing wildlife. This is the best opportunity many of the campers have to commune with nature, and it provides wonderful educational opportunities for urban children to become better aware of wildlife ecology.

Many photographers take advantage of the wildlife models available in and around campground areas. These animals are often easily photographed at close distance due to their tendency to approach in order to beg for food. With very little effort, professional photographers can obtain profitable studies of wildlife in their seminatural habitat; for the amateur photographer, even rodents provide interest in what would otherwise be repetitive photographs of static vegetation.

Rodent populations, if not too dense, can contribute to the quality of campground areas not only in an aesthetic way, but by serving indirect functions such as providing food for predators and perhaps aiding in the soil nutrient cycle. The carnivorous predator species play an important role in forest wildlife ecology. However, these predators must have rodent prey populations in order to survive and reproduce in the area. For many avian predators the amount of successful nesting and other breeding activity varies with the availability of rodent prey.

In addition to serving as prey for predators, rodents can function as predators themselves, especially chipmunks, deer mice, and ground squirrels. In the warmer months of the year, ground-dwelling insects and insect larvae are important in the diet of these rodents. Studies have shown that when deer mouse populations increase in a given area, the density of certain forest insect pests may be decreased dramatically. Both deer mice and chipmunks are considered by some foresters to be significant insect predators.

An often overlooked possible contribution made by rodents lies in their tendency to burrow extensively, moving enormous quantities of earth, much of which is also exposed to erosion. During active burrowing, rodents finely pulverize the soil, mixing the different soil layers together with plant material, old nests, and the decayed bodies of former burrow residents. Both beneficial changes in soil porosity and increased susceptibility to erosion have been attributed to the activities of burrowing rodents.

B. Natural History of Key Rodent Species

For the ranger or forester to fully understand the complexity of managing rodents, identification of the species is necessary as well as some basic knowledge of their natural history. It is virtually impossible to attempt to manage a species without knowing of its annual cycle, preferred habitat reproductive potential, feeding preference, activity habits, and propensity for carrying diseases.

Important biological and ecological information is being provided for some of the key rodents found in campgrounds. Those included are considered the most important from an economic and public health point of view. The list includes those species which become most numerous in or near campground facilities. Although not rodents, we have included moles because of their fossorial habits which often confuse them with pocket gophers.

No attempt is made to list all the species of rodents that may frequent Forest Service campgrounds and may, at one time or another, create potential or actual public health problems or be implicated in structural or other facility damage. For example, the natural history is not included for the antelope ground squirrel (Ammospermophilus leucurus), Townsend's ground squirrel (Spermophilus townsendii), Belding's ground squirrel (Spermophilus beldingi), rock squirrel (Spermophilus variegatus), round-tailed ground squirrel (Spermophilus tereticaudus), Douglas tree squirrel (Tamiasciurus douglasii), and yellow-bellied marmot (Marmota flaviventris), yet all may dwell in or near campgrounds. The natural history of these species may be found in references such as Mammals of the Pacific States (Lloyd G. Ingles, 1965). Also not included are the lagomorphs (jackrabbit, Lepus spp., and cottontails and brush rabbits, Sylvilagus spp.), many of which are classified as game animals in California. Beaver (Castor canadensis) have been omitted because they rarely occur in campgrounds; they can, however, be involved in potable water contamination with such diseases as tularemia and leptospirosis. Where beavers are of concern or a problem, consult the California Department of Fish and Game for management information and guidelines.

The three nonnative rodents--Norway rats, Rattus norvegicus, roof rats, R. rattus, and house mice, Mus musculus--have not been included in this volume although, depending on the campground location, any one or all of these species may be pest problems at least occasionally. The control of these species usually falls under structural pest control for which there are adequate policies and procedures already established.

1. California ground squirrels

Distribution: California ground squirrels are widely distributed throughout the state. Six subspecies of Spermophilus beecheyi are recognized, possessing distinct geographic ranges and sometimes responding differently to control techniques. The more common of these subspecies are: The Beecheyi ground squirrel (S. beecheyi beecheyi) inhabiting coastal California from San Francisco south almost to San Diego; the Fisher ground squirrel (S. beecheyi fisheri) occupying central California east of the Feather and Sacramento Rivers south to the southern end of the San Joaquin Valley; and the Douglas ground squirrel (S. beecheyi douglasii) found from San Francisco to the Oregon border, west and north of the Sacramento River. Of more limited distribution are the Sierra ground squirrel (S. beecheyi sierrae), occuring in the northern high Sierra; the Juarez ground squirrel (S. beecheyi nudipeds) found in the southwest corner of the state; and the lesser California ground squirrel (S. beecheyi parvulus) of the desert ranges of Southern California between Owens Valley and Mt. San Jacinto.

Habitat: California ground squirrels generally live in open habitats such as grazed grassland, pastures, grain fields, open forests, and rocky ridges. They are often favored by the presence of rocks, logs or other objects for shelter or under which they construct their burrows. They usually avoid thick chapparal or dense woods, but road development has often enabled them to disperse deep into otherwise unfavorable habitats.

Appearance: California ground squirrels have a brownish head and body, flecked with buff or buffy white. A conspicuous dark triangle is found on the back between the shoulders on the Douglas ground squirrel. The belly is buff and the tail is moderately bushy.

Burrows and nests: Burrows are about 4 to 6 inches in diameter and from 5 to 200 feet (1.52-61 m) long, often with many openings and with runways between holes and to feeding areas. The tunnel system is usually between 2 1/2 to 4 feet (0.76-1.22 m) deep. The volume of any given burrow system ranges from between 1 and 18 cubic feet (0.03-0.5 cu m). They may be simple tunnels or have extensive branches. Most are colonial burrows occupied by several squirrels, and these burrow systems may be used for many years. A nest made of finely shredded grass is normally located in a chamber above and to one side of the main tunnel. It is thought that when these nests become heavily infested with fleas some squirrels may temporarily leave and occupy other burrows in the colony. For the most part squirrels annually remodel existing burrow systems and rarely abandon them completely. If the squirrels are artificially removed from the burrow system, other squirrels will soon move in to reoccupy. The establishment of an entirely new burrow system or colony is generally done by the young which leave the home colony. Certain types of soil disturbance such as road building tend to favor burrowing and expansion of populations.

Food: During the rainy season (normally November to April), ground squirrels feed on green vegetation and seeds lying on the ground. When the new seed crop ripens, the squirrels gather seeds and cache them in shallow holes or in crevices between rocks. Ground squirrels also eat acorns, mushrooms, fruits, berries, birds' eggs and insects. Gathering of food is facilitated by well-developed internal (membrane-lined) cheek pouches. Large underground food caches are usually not found when burrow systems are excavated.

Biology: California ground squirrels are diurnal and colonial. The adults commonly undergo both a winter hibernation and in some areas summer

estivation. At the lower elevations adults normally estivate by July and the young by September, although this varies with geographic location. Depending on the altitude the young may not estivate or hibernate and remain active year-round if weather conditions permit. Estivation of adults often carries over into a true hibernation at low elevations. During estivation or hibernation the squirrel retreats to its nest and curls up tightly in a sitting position. The burrow entrances are left open, but the burrow is plugged further in. During this period, the heartbeat and respiration rates are greatly slowed and body temperature drops almost to the temperature of the burrow. The squirrel survives on fat stored up beforehand. Emergence is in late winter (as early as the end of January) or in early spring.

Activity of California ground squirrels varies seasonally, differing somewhat for males and females. Immediately after hibernation, males will be predominantly active. As the breeding season nears, females will more often be seen above ground until the sex ratios are nearly equal. Later in the year the adults will estivate or hibernate earlier than the young, which may remain active year-round.

Ground squirrels may be preyed upon by coyotes, foxes, weasels, badgers, bobcats, golden eagles, hawks, rattlesnakes, and gopher snakes.

Breeding and young: The breeding season is usually from February to April, but breeding may begin as early as December in Southern California and continue through late spring in other areas. The gestation period is 25-30 days, with an average litter size of 7 (ranging from 1 to 15). One litter is produced per year. The young remain underground for 6 weeks, and some may disperse to new territory a few months after emergence. The young become sexually mature at about 1 year of age.

Population characteristics: California ground squirrels may disperse when young into unoccupied burrows or new areas, sometimes traveling up to 5 miles (8 km). They may live up to 5 years or more in the wild.

Disease implications: California ground squirels are a major link in the transmission of sylvatic (bubonic) plague to humans. Although not the true reservoir hosts of the disease, ground squirrels are highly susceptible to epizootic outbreaks that can spread in bubonic form to humans. Over half of the reported human plague cases in the last 40 years can be circumstantially attributed to ground squirrels and their fleas. They are also implicated in the spread of Rocky Mountain spotted fever and tularemia, as well as other diseases of less public health significance such as rat bite fever, Chagas' disease, encephalomycarditis, adiospiromycosis, California encephalitis, and probably Colorado tick fever and Murine typhus also.

Economic importance: California ground squirrels damage a wide variety of agricultural crops including grain crops (all types), nuts (almonds, pistachios, walnuts), fruits (peaches, apples, apricots, oranges, prunes, olives, figs), vegetables, and field and forage crops. Ground squirrels are capable of substantial competition with cattle for grazing land, directly by their consumption of grass and indirectly by regarding early growth. Ground squirrel burrowing often damages levees, earth dams, irrigation canals, ditch banks, dirt roads, and railroad rights-of-way. In campgrounds they burrow beneath buildings causing concrete slab foundations to crack. Picnic tables, stoves, fire pits, toilets, and paved campground spurs all may be undermined by burrows, causing serious structural damage.

2. Golden-mantled ground squirrels

Distribution: The golden-mantled ground squirrel (Spermophilus lateralis) is found at higher elevations in the mountains of California, except for the Coast Range south of San Francisco. It inhabits the Sierra Nevada, Trinity and San Bernardino Mountains, including a wide area in the northern part of the state.

Habitat: Mountainous areas (Transition and Canadian Life Zones) open to moderately dense coniferous forests, chaparral, sagebrush, and above timberline. They favor rocks and logs which provide them with a good view of their surroundings.

Appearance: A small ground squirrel which appears like a large chipmunk, but having no stripes on the side of the face. The head and shoulders are golden or coppery, contrasting with the body; one white stripe bordered with two black stripes runs down each side of the body (chipmunks have two white stripes on each side). The hairy tail is fairly short and not bushy.

Burrows and nests: The burrows are located close to or beneath rocks, bushes, trees, logs, and stumps, although they may be out in the open as well. Burrow openings are inconspicuous as compared to those of other ground squirrels. Little or no excavated earth is left by the entrances. The openings are 2 to 3 inches in diameter, and often there are two or more openings to a burrow. The entire tunnel system may be 17 feet (5.2 m) long, running for the most part about 8 inches (20 cm) deep. The burrow system may contain side tunnels and a nest chamber lined with shredded grass, bark, leaves, stems, conifer needles, and perhaps paper or cloth.

Food: Reportedly leaves and hypogeous (i.e., subterranean) fungi constitute 87% of their diet. In some areas leaves of woolly mule ears (Wyethia mollis) were eaten more than any other plant. Later in the year,

the golden-mantled squirrels feed on Wyethia flowers. They also favor the bulbs of wild onion (Allium spp.) Fungi are of major importance in their diet, and the forest floor is often covered with holes where they have dug for these small modules. In September and October the squirrels switch to feeding on the ripened conifer seed. In addition, golden-mantled squirrels will consume many other types of green vegetation, shrub and herb seeds, berries, insects, larvae, young birds and eggs, and when available, meat. Although they will readily feed on dead or trapped chipmunks, they apparently are seldom able to capture them under normal conditions. Golden-mantled squirrels gather food in well-developed internal (membranous) cheek pouches and store it in caches. Food may be temporarily stored in shallow pits and covered up with dirt, or it may be cached in more permanent hoards in the burrow system.

Biology: Golden-mantled ground squirrels are diurnal. They seek sun and warmth, becoming active around sunrise and disappearing quickly after sunset. They avoid the heat of the day, and in midsummer they may be inactive between 9:00 a.m. and 4:00 p.m. as a result. Golden-mantled squirrels undergo a winter hibernation beginning in late summer or fall. Adults generally enter hibernation one or two months before the juveniles. Some adults may undergo summer estivation in years of plentiful food. Some squirrels arouse periodically from hibernation and appear above ground in winter. Their tracks are frequently seen on top of the snow. They store up large quantities of fat underneath the skin and elsewhere in their bodies and are thus able to survive long periods of deep torpor without eating. It is believed that the burrow food caches are utilized only occasionally during the winter, mainly being used in early spring when hibernation is over. Emergence is in spring (March-May), and appears to be in response to an

endogenous (internal) rhythm rather than in response to weather conditions alone.

Known predators of the golden-mantled ground squirrel include coyotes, foxes, weasels, bobcats, red-tailed hawks, snakes, and sometimes striped skunks.

Breeding and young: Males are fertile on emergence from hibernation. Females come into estrous shortly afterwards. Mating occurs over a 4-week period, mainly during the latter part of April and early May. However, there is a great deal of altitudinal and geographic variation in the timing of the breeding season. One litter is produced per year, with an average litter size of 5 (ranging from 2 to 8). The gestation period is 27-28 days. The young are born from mid-May to early June, with the juveniles appearing in the above-ground population about 5 to 6 weeks later. The young begin to eat solid food at 40 days of age, and are fully weaned 6 to 8 weeks after birth. Sexual maturity is attained the following spring.

Population characteristics: The sex ratio in the overall population is close to 1:1. Males are observed more frequently in winter and early spring, as they arouse from hibernation and emerge earlier than do the females. Adult males also appear to enter hibernation later than do females. Thus males will be predominantly observed in early spring, late summer, early fall and winter, whereas females will be more prevalent during late April and early May.

Golden-mantled squirrels are most easily trapped during times of scarce food (e.g., in spring) and during the breeding season when they are apparently less cautious.

Only about one-third of the spring population survives to the next year. Adults have about a 6% higher annual survival rate than the juveniles. Less than 1% of the population survives beyond 4 years.

Their home range is under 200 yards (183 m) across, but foraging activity is extensive throughout the area. Males have larger home ranges than females. About half of the juveniles, especially the males, will emigrate to new areas. They can disperse at least 2.5 miles (4 km) to colonize a new habitat. The combined effect of long-distance dispersion and high mortality is such that less than one-tenth of the juveniles remain longer than one year in the vicinity of the breeding population.

Social organization: Golden-mantled ground squirrels do not exhibit the highly developed social behavior of many other ground squirrels. However, they do communicate and interact in other ways to a limited extent. This species possesses dorsal and anal scent glands which appear to function in olfactory communication of age, sex, and group or individual identity. Most communication is through vocalization, particularly alarm calls. Golden-mantled squirrels react strongly to alarm calls of other conspecifics as well as to alarm sounds of chipmunks, jays, woodpeckers, tanagers, grosbeaks, and rock wrens. They will pay little attention to the normal voices of other animals, though.

Golden-mantled squirrels actively defend a small territory around the den but do not defend the boundaries of their home ranges. There may be considerable overlap in their home ranges, as these are from 1 to 10 acres (0.4-4 ha) in size and ordinary densities are 2 to 5 animals per acre (4.9-12 animals per hectare). Territoriality regarding the home den should not be confused with the social ranking or chase order that is established around a favored food supply. In this case the animals will quarrel and chase each other attempting to gain control of the food, quickly setting up a dominance hierarchy. Although these squirrels often engage in brief fights, such conflict is mostly display and rarely do they seriously harm one another.

There is virtually no cooperation between individuals. They will congregate in large numbers around food, but there is little interdependence other than vocalizing alarm calls and observing the gathering of other individuals around a food source. Family life is brief, females taking care of the young without any involvement from the male. The family usually breaks up as soon as the young can care for themselves.

Disease implications: Golden-mantled ground squirrels are highly susceptible to sylvatic plague, and present potentially major public health problems in campgrounds and other areas within national forests. Because they can become very numerous, very tame, and often in close contact with park or campground visitors, transmission of plague to humans is quite possible whenever an epizootic is occurring. They may also carry other diseases such as Rocky Mountain spotted fever, various tick fevers, and others.

Economic importance: They may cause damage to reforestation attempts that utilize seeds, but, because they inhabit high-altitude areas, are of little agricultural importance. If allowed to become too numerous, golden-mantled ground squirrels may become a nuisance to campground visitors by invading food stores and causing damage to facilities by gnawing or burrowing.

3. Chipmunks

Distribution: There are ten species of Eutamias in California, inhabiting virtually all the mountain ranges in the state. The ten species and their approximate distributions are as follows:

E. townsendi: Sierra Nevada, northern coastal and inland ranges.

E. speciosus: Sierra Nevada, San Gabriel Mountains and other southern California ranges.

E. umbrinus: Sierra Nevada from Mammoth Pass south into Inyo County, and the White Mountains.

E. merriami: Sierra Nevada south of Tuolumne County, Coastal Range south of San Francisco, many ranges of southern California.

E. amoenus: northern Sierra Nevada, northern ranges.

E. minimus: east side of Sierra Nevada and ranges to the east, northeastern ranges.

E. sonomae: northern coastal ranges, other ranges in northwestern California.

E. quadrimaculatus: Sierra Nevada from Plumas County south to Madera County.

E. alpinus: High Sierra Nevada from Tuolumne County to Olancha Peak.

E. panamintinus: east side of Sierra Nevada between Bishop and Olancha Pass; Panamint, White, Cocos, Inyo, Argus, and Providence Ranges.

Habitat: Chipmunks appear in a wide variety of habitats, generally preferring open coniferous forests, but they are also found in chaparral, oak woodland, pinyon-juniper woodland, sagebrush, and open rocky areas. Most species are favored by the presence of rocks and brush in the habitat, and usually require the presence of trees.

Appearance: California chipmunks are small, much smaller than any ground or tree squirrels. They are brightly colored, with four light-colored stripes

separated by darker stripes on their backs. Similar in appearance to the golden-mantled ground squirrel, they can be differentiated in that chipmunks have stripes on the sides of their face and possess twice as many light dorsal stripes. Their tails are fully haired but not bushy.

Burrows and nests: Chipmunks may build nests in holes in trees (e.g., abandoned woodpecker holes) or in ground burrows, depending on the species. Nests are usually made of shredded leaves and lichen. The burrows of chipmunks are much less noticeable than those of most ground squirrels. They do not construct conspicuous mounds and there are no obvious paths leading to the mouth of the burrow. The burrow opening is usually under the edge of a stone or under a stump or tree root. The burrows are about 2 inches (5 cm) in diameter and several yards (meters) long, with branching tunnels and occasional chambers. The depth of a tunnel system varies from 1 to 4 feet (0.3-1.2 m).

Food: Chipmunks feed on all manner of nuts and seeds, as well as grain, fruits, fungi, insects, bulbs, roots, leaves and flowers of a wide variety of plants, bird eggs, young birds and other meat when available. Chipmunks gather food in membranous (internal) cheek pouches and cache it underground.

Biology: Chipmunks are diurnal and have a longer activity period than California or golden-mantled ground squirrels. They are active an hour before sunrise and remain out a half hour before sundown. They avoid the midday heat by retreating into their burrows or remaining in shade. In midsummer this period of inactivity may prevail from 9:00 a.m. to 4:00 p.m. At the higher elevations chipmunks undergo a winter hibernation beginning about November. Since they do not store large quantities of fat in their bodies, chipmunks survive the winter on cached food. This food is stored in the nest itself and is thus readily available whenever the chipmunk awakens. They do not enter into a deep torpor as do ground squirrels, but remain

relatively inactive during winter until about March. They are less often seen in winter than the golden-mantled squirrels. In regions where snowfall is light, they enter hibernation later and emerge earlier than the golden-mantled squirrels. If the snow is very light, they disappear during the storm and emerge when the snow melts. In the low desert regions they may remain active year-round. Neither adults nor juveniles appear to estivate.

The main predators of chipmunks include coyotes, bobcats, weasels, badgers, and hawks. Chipmunks are also occasionally preyed on by rattlesnakes, pygmy owls, golden eagles, skunks, foxes, martens, fishers, and wolverines. They are commonly parasitized by botflies (Cuterebra spp.), although the wounds heal readily.

Breeding and young: Males are fecund on emergence from hibernation. The females become estrous somewhat later (late March-early April). Mating occurs over a 4-6 week period from about April to mid-June. Some may produce 2 litters annually, but most produce 1 per year. The gestation period is 31 days. There are from 2 to 7 young per litter, born in May or June. The young are born naked and blind and are weaned at 6 weeks. They appear in the above-ground population about a month after birth. The young are sexually mature the following spring.

Population characteristics: Data regarding the sex ratio of chipmunk populations are conflicting. Some researchers have found equal sex ratios while others have found more males than females (both adults and juveniles). One study revealed 72% of E. amoenus lived at least 9 months, and 3-5% lived at least 3 years. The maximum longevity is at least 6 years. Mortality is about the same for males and females during the first few years, but females lived longer. Cameron (1969) indicates that the general survival rate is about 50%, i.e., about half of the population survive from one year to the next. Mortality over the winter is about 23%; it thus appears that

chipmunks survive the winter more successfully than the golden-mantled ground squirrels.

Social organization: Chipmunks are not very territorial except in defense of nests and do not disperse as readily as the golden-mantled ground squirrels. They do, however, forage over very large home ranges. Seventy-one percent of females may move up to 500 feet (153 m) in a day, 71% of the males may move up to 1,100 feet (335 m) daily, and some individuals will forage up to 2,400 feet (732 m). Juveniles disperse mainly in July through September. Foraging distance and emigration seem to increase as a function of decreasing food supply. Chipmunks communicate through the use of alarm calls and perhaps olfactory communication (scent glands) as well.

Disease implications: Chipmunks and their ectoparasites may carry bubonic plague and Rocky Mountain spotted fever as well as other diseases less hazardous to public health. Being fairly numerous and often quite tame, shipmunks can readily transmit diseases to man if their populations are allowed to become excessively high or if allowed into close contact.

Economic importance: Around campgrounds or cabins chipmunks often get into food or grain supplies and may be a nuisance to campers if allowed to become too numerous. Chipmunks can unfavorably influence reforestation where it relies on seed survival, but they are of little economic importance in cultivated agriculture.

4. Western gray squirrel

Distribution: Gray squirrels (Sciurus griseus) are found in valleys, foothills and mountains throughout California, except for the Central Valley, the deserts and eastern portions of the state.

Habitat: Open coniferous and deciduous forests, especially oak woodland.

Appearance: A large gray tree squirrel with a long very bushy tail and a white belly. Their coloration and very bushy tail distinguish them from the introduced eastern gray squirrel or the fox squirrel, which are found primarily in the lower valleys and in the parks of some of our larger cities.

Burrows and nests: Sometimes gray squirrels live in nests made of sticks, shredded bark, leaves, and grasses, with the entrance located in the side; but they are commonly found nesting in hollow cavities in trees. The nests are usually more than 20 feet (6 m) off the ground.

Population characteristics: Western gray squirrels live up to 11 years in captivity. Populations range from 10 squirrels per acre (25 per ha) to 1 squirrel per 10 acres (1 per 4 ha), with the average around 1 squirrel per 1.5 acres (1 per 0.6 ha).

Social organization: Females display territorial behavior when young are in the nest. The home range covers an area of about 1/2 to 2 acres (0.2-0.8 ha).

Disease implications: Gray squirrels carry diseases such as murine typhus, sylvatic plague, rabies, and tularemia. They also are known to carry toxoplasmosis, western encephalitis, encephalomyocarditis, endemic relapsing fever, and ringworm. All of these may be transmitted to man.

Economic importance: The western gray squirrel may cause structural damage by gnawing into buildings or damaging telephone cables. However, they do not become as abundant as the ground squirrels or chipmunks. Locally they can be an agricultural pest in walnut, almond, avocado and citrus orchards.

5. Deer mice

Distribution: There are six species of Peromyscus in California. P. maniculatus (deer mouse) is most common, occurring throughout the state. P. boylei (brush mouse) and P. truei (Pinon mouse) are also fairly widespread in California. P. eremicus, P. crinitus and P. californicus have smaller ranges throughout the southern half of the state. The ranges of the various species overlap substantially.

Habitat: P. maniculatus occur in nearly every dryland habitat from sea level to above timberline, including desert areas. P. boylei inhabits chaparral and rocky areas of arid or semi-arid regions (Upper Sonoran Life Zone); P. truei is found in rocky terrain and brush associated with pinyon-juniper woodland and foothill woodland (Upper Sonoran Life Zone). P. crinitus lives in rocky places, canyons, and old lava flows of the Upper Sonoran and Transition Zones of desert mountains. P. californicus is found in chaparral and oak woodland in the Upper Sonoran Life Zone.

Appearance: Peromyscus spp. are medium-size mice with white feet, usually white bellies, and variable in color, but normally some shade of brown or gray. They have large membranous ears, grooveless upper incisors, which distinguish them from harvest mice (Reithrodontomys spp.), no external cheek pouches, and a tail almost as long or longer than the head-and-body length.

Burrows and nests: The nest may be found in rotting logs, stumps, among rocks, underground in burrows, or inside buildings. The nest consists of dry grass, soft plant parts, hair, feathers, seed hulls, shredded paper or any other available materials.

Food: Deer mice eat a wide variety of seeds, nuts, acorns, fruits, and insects. They have been known to consume more than 200 Douglas-fir seeds per day. Feeding habits may vary seasonally, with larvae and insects being

consumed in spring while seeds constitute the bulk of the diet during the fall. Deer mice gather and store large caches of food (primarily seeds) for winter use.

Biology: Deer mice are primarily nocturnal. They are less active on very dark or bright moonlit nights, becoming active shortly after sunset (half an hour to an hour afterwards) and retiring about an hour before sunrise. The length and timing of the activity period varies seasonally, the circadian rhythm being adjusted in response to light. Deer mice do not hibernate, although they may become torpid for a few days at temperatures below 59°F (15°C). They appear above snow in winter as well as being active in tunnels beneath the snow.

Peromyscus are preyed upon by virtually every bird and mammal predator in California. In some habitats deer mice are often a major source of food to some predators.

Breeding and young: The breeding season extends from February through November. Between 2 to 4 litters are produced per year. The litter size varies between species and populations due to genetic and environmental differences. It averages from 2 to 5 young per litter, but may be as few as 1 or as many as 8. The gestation period averages 24 days, ranging from 21 to 27. The young are pinkish at birth in most species, becoming pigmented several days later. The newborn young frequently vocalize in high-pitched squeaks and other sounds. The eyes open from 10 to 28 days of age. Weaning occurs at 3 to 4 weeks, although the young may remain with the mother as long as 60 days of age. Sexual maturity is attained between 40 to 70 days, varying considerably between species.

Population characteristics: The size of the population varies seasonally, with the fall populations being the largest. Peromyscus appear to have

efficient population-controlling mechanisms which maintain low densities, usually under 10 per acre. Irruptions of deer mice sometimes occur in logged areas. Most species of Peromyscus have unequal sex ratios, there being more males than females. It is possible, though, that this is an artifact due to males being more readily trapped.

Deer mice make their major dispersal movements, if they disperse, when they mature sexually for the first time. Some (2 females to every 1 male) are predisposed to make extensive dispersals (innate dispersants), whereas the others which disperse (environmental dispersants) usually travel less distances and do so because of population pressures. Innate dispersants have traveled over 3,000 yards (1,000 m) before establishing a new home range.

Wild deer mice, like other rodents, do not reach a very old age. Probably less than one-fifth reach sexual maturity. Estimates range from 63 to 99% mortality over a one-year period. Deer mice rarely live over two years in the wild, although they have been kept up to eight years in captivity.

Social organization: The degree to which social structure is developed varies between the different species of Peromyscus. Most exhibit a loose social structure, mainly during the breeding season. Male-female pairing occurs and such bonds may last until the young are born. Some species form family groups and may be monogamous. Large groups of adults and juveniles may winter together.

Territoriality is often exhibited by the female in the immediate vicinity of the nest. Adult females appear to repel other females from definite territories, at least during the breeding season. Home ranges of both sexes may overlap, and there may be a dominance hierarchy superimposed on the system of territories and home ranges. The size of the home range may vary from 0.1 to 10 acres (0.04-4 ha).

Deer mice communicate through vocalizations as well as tactile, visual and chemical means. Scent glands may produce chemicals that serve to identify the sex, age, species, social group, individual identity, or physiological state of an animal. In addition, tactile or visual cues are important in communicating dominance or submission, sexual receptivity, and other responses during encounters between individuals.

Disease implications: Peromyscus are thought to be of major importance in the maintenance and transmission of sylvatic plague. Deer mice possess all the requisites of a reservoir species. They are partially resistant to plague and can maintain it in enzootic form within the population, they have a very wide geographic range, are found in a variety of habitats, and, most important, they often are closely associated with many other rodent species that are highly susceptible to plague epizootics. For example, it is speculated that plague may go from deer mice to ground squirrels to man.

Other diseases which deer mice have been found to harbor include tularemia, leptospirosis, and tick-borne rickettsioses such as Rocky Mountain spotted fever and Q fever. Rarely they may be carriers of diseases such as adiaspiromycosis and coccidioidomycosis.

Economic importance: Deer mice can be troublesome by gnawing on camping equipment or getting into food stores in campgrounds. They sometimes get into house trailers, campers and automobiles and use the upholstery for nesting materials or nesting sites.

Deer mice can be a serious problem in forest regeneration. Reforestation attempts through direct broadcast seeding of conifers have been severely hampered by Peromyscus. Seeds and seedlings of Douglas-fir, ponderosa pine, and other conifers are extensively harvested by deer mice. Because they favor areas opened by fire or logging, these rodents can build up to considerable densities and make much reseeding of conifers difficult. Since

each mouse is capable of consuming 200-300 Douglas-fir seeds per day, high population densities can result in total failure of a regeneration effort. It has been shown that only 2 rodents per acre (0.8 per ha) can destroy in 35 nights the entire seed stock normally broadcast.

In agricultural areas, Peromyscus also may harvest planted melon seeds and alfalfa seed.

6. Wood rat (other names: pack rat, trade rat, brush rat, mountain rat, cave rat.

Distribution: One or more of the four species of Neotoma can be found in almost any area of California. N. fuscipes, the dusky-footed wood rat, lives in the Upper Sonoran and also Transition Life Zones on the western slopes of the Sierra Nevada, and in the coast ranges from Mexico to Oregon. N. lepida, the desert wood rat, inhabits most of the state south of the San Joaquin River, as well as a small area in Lassen and Modoc Counties. N. albigula, the white-throated wood rat, occurs only in the southeastern corner of the state. N. cinerea, the bushy-tailed wood rat, is found in the central Sierra Nevada and northeastern portions of the state, and westward into the northwestern corner of California.

Habitat: N. fuscipes inhabits heavy chaparral, streamside thickets and deciduous or mixed woods (especially oaks). N. lepida inhabits desert floors or rocky slopes with scattered cactus, yucca or other low vegetation. N. albigula lives in brushland and rocky cliffs with shallow caves. N. cinerea is found in high mountain pine forests, rock slides and rimrock.

Appearance: The native wood rat superficially resembles the introduced Norway or brown rat but is easily distinguished from the latter by having a hairy rather than scaly tail and possessing soft fine fur. Neotoma have larger ears and white feet and bellies and are very different in nesting habits. Wood rats are not found in as close association with man as are the introduced Old World rats.

Burrows and nests: Wood rats build nests of sticks or other available materials and are usually located in thick brush, trees, rock crevices, cactus patches, or on cliff ledges. The nests are irregular piles or cone-shaped houses up to 4 feet (1.2 m) or more in height and diameter, with numerous well-worn entrance holes around the base. Inside near the top can be found a nest chamber lined with finely shredded bark or grasses. Other food storage or waste-disposal chambers may also be present.

Food: Wood rats commonly damage conifers or orchard trees through bark-stripping and removal of small side branches, but this is apparently usually for nesting materials rather than food. Wood rats are primarily vegetarians, feeding on green vegetation, seeds, nuts, acorns, fruits, fungi, and cactus, depending on what is available in the habitat. They may enter cabins or buildings in rural areas in search of food and nesting sites.

Biology: Wood rats are mainly nocturnal and do not venture out in bright moonlight. They are good climbers but are not particularly arboreal. Wood rats are active throughout the year. Known predators of Neotoma include coyotes, foxes, weasels, ringtails, bobcats, owls, and large snakes.

Breeding and young: Most breeding occurs from about May to August, but wood rats may breed as early as January or as late as October depending on the species and the favorability of the habitat. The gestation period is approximately 30-36 days with litter sizes ranging from 1 to 5, typically 2 or 3. The young are born partially pigmented and blind. Eyes open at about 13 days, and the young are sexually mature at 60 days. An adult will produce from 1 to 4 litters per year. The young often live in the nest until they are nearly full grown, at which time they may move to an unoccupied nest, or the mother may leave the nest to the young and move a short distance to a new site.

Population characteristics: There appears to be a high mortality of young by the end of summer, although individuals have been known to live four years in the wild. Populations of N. albigula may reach densities as high as 10 to 20 adults per acre (25-50 per ha). Home ranges are fairly small, around 100 to 150 feet (30-46 m) across. Wood rats exhibit territorial behavior regarding their nests.

Disease implications: Wood rats carry Rocky Mountain spotted fever and sylvatic plague. Their tendency to enter cabins and other rural buildings in search of nesting materials, nest sites, or food can lead to potential public-health problems in any area infested with either disease. Outbreaks of sylvatic plague in wood rats frequently coincides with epidemics in ground squirrel populations. In addition, wood rats can carry other diseases of relatively minor public-health significance such as Colorado tick fever.

Economic importance: Wood rats occasionally take up residence in mountain cabins and rural dwellings where their noise and theft of food and small articles can be a nuisance, and the accumulation of their droppings undesirable.

Only seldom do wood rats become numerous enough to be more than a minor agricultural pest. They can inflict limited damage to field crops and gardens. Wood rats occasionally carry off significant quantities of valuable nut crops. They also can damage orchard trees by their bark-stripping activity. Conifers in tree plantations may likewise be damaged by girdling and stem-pruning, and reseeding efforts may be hampered by wood rats gathering conifer seed. However, compared to many other wild rodents, wood rats are generally only of very local economic importance to forestry and agriculture.

7. Porcupine

Distribution: Porcupines (Erethizon dorsatum) are found throughout most of the coniferous forests of California, inhabiting the Coast Range north of Marin County, the northern ranges of the state, the Sierra Nevada south through the Tehachapis, and the San Bernardino Mountains.

Habitat: Porcupines inhabit coniferous forests but occasionally are found away from trees where brush is present.

Appearance: The porcupine is one of the largest native rodents, sometimes weighing over 30 pounds (13.6 kg). They are heavy-bodied with short legs, black in color with yellow-tipped hairs. Porcupines are the only North American rodent with long sharp spines and quills. The quills cover most of the body, being especially heavy on the rump and tail.

Burrows and nests: Porcupines rest in the dense foliage of particular trees or in a cave near their feeding grounds. Here there will usually be hundreds of brownish oval-shaped fecal pellets about 5/8 inch (1.6 cm) wide. In response to harsh weather, porcupines often move to sheltered trees or dens during the fall and winter. Dens may be in rock crevices, caves, and hollow trees or logs.

Food: During spring and summer porcupines feed on herbaceous vegetation, primarily succulent herbs and shrubs, as well as the buds of conifers. During fall and winter porcupines feed on the needles, inner bark and cambium of conifers, especially ponderosa pina and juniper. They also feed on apples and other fruit, mistletoe, alfalfa, sweet corn, and young trees in orchards. They are highly attracted to salt and are frequently seen on the shoulders of roads that have been salted.

Biology: Porcupines are nocturnal but are often seen during the day, especially in the tops of trees. They are arboreal in their habits, although ground-feeding is common during parts of the year. They do not hibernate. Somewhat slow-moving and clumsy, they are nonetheless excellent climbers and are capable of swimming. Porcupines produce grunts, groans, and high-pitched cries that may be heard for a quarter mile (0.4 km), especially during the fall mating season.

The stiff quills of the porcupine are loosely attached, modified hairs with back-slanting microscopic barbs. Since most wild animals are incapable of removing them, a quill can continue to work in deeper and may eventually penetrate a vital organ. When attacked, porcupines lower their heads between their front legs and erect the quills on their backs. They slap an attacker with their tails, which drives dozens of quills into the enemy. Porcupines do not "throw" their quills, although the spines may become loosened in a severe fight and fly aimlessly about as the tail is lashed back and forth.

Despite their effective defense mechanism, porcupines occasionally fall prey to mountain lions, bobcats, fishers, wolverines, and coyotes. Fishers are perhaps their most important predator. Porcupines are vulnerable to attacks on their bellies, which are spineless.

Breeding and young: Porcupines breed during the fall (September through December) and the young are born in April, May or June after a seven-month gestation period. One litter of 1 or 2 young is produced per year. The young are large and active, born with fur, spines, and open eyes. The quills are soft at birth but become hard and sharp as soon as the baby is dry. Within a few hours after birth, porcupines are able to eat solid food and can climb trees. Within two days, the young will follow the mother on feeding trips and are completely weaned after ten days. The young remain with the mother for 5 or 6 months, after which they are fairly solitary. Porcupines are sexually mature at 3 years.

Social organization: Porcupines are solitary except during the fall mating season and when denning in winter.

Disease implications: Only very rarely are diseases transmitted to man from porcupines. Although they may carry diseases such as tularemia, Rocky

Mountain spotted fever, and Colorado tick fever, their solitary habits render them of minimal public-health significance.

Economic importance: Porcupines damage young conifer trees and seedlings during forest regeneration efforts. Porcupines also damage trees by bark-stripping and girdling in orchards and tree plantations. Even very large trees can be injured, as the porcupine frequently feeds at the tops of trees. Leather boots, saddles, ax handles, outside toilets, or other items in campsites are often gnawed on by porcupines, presumably to obtain salt residue from perspiration. Locally porcupines also sometimes damage crops such as sweet potato, corn, alfalfa, apples, and other fruits and vegetable crops. However, they are not generally considered an important agricultural pest.

8. Meadow mice (voles)

Distribution: Five species of Microtus are found within California: M. californicus is found in the Owens, Central, and lowland valleys as well as in the Coast Range; M. montanus inhabits northeastern California and the slopes of the eastern Sierra Nevada; M. longicaudus occurs throughout the Sierra Nevada and the northeastern and northwestern ranges; M. oregoni and M. townsendi occupy the northwest corner of the state.

Habitat: Microtus require a good grass cover but on grazed rangeland they may be associated with grassy springs, seeps, and semi-wet areas. In general, meadow mice are found in grassy areas such as mountain or lowland meadows, roadsides, ditch banks, fence rows, irrigated pastures, orchards (cherry, citrus, apple, and others), conifer and hardwood tree plantations, alfalfa, clover, hay and grain fields, and vegetable crops (including sugar beets, potatoes, cabbage, artichokes and carrots). The various species of Microtus differ somewhat in their choice of habitat.

Appearance: Voles are large mice about 4 to 6 inches (10-15 cm) in length, ranging in size from the Oregon vole, which weighs about 20 grams, to the California vole that may weigh up to 100 grams. They are mainly brownish gray with small ears and a relatively short tail which is always less than the head-and-body length. Their fur is relatively long for a mouse and soft, and they have small, black, beadlike eyes.

Burrows and nests: Microtus burrow openings are distinctive in being round and open, connected with 1 to 2-inch (2.5-5 cm) wide surface runways along which they forage. Short pieces of clipped vegetation and feces along these runways are indicative of their activity. M. longicaudus do not maintain such well-defined runways, however.

Food: Voles are herbivorous and seek out seedlings and succulent stems, but also feed on seeds and fruits. In late fall and winter, lack of other forage apparently causes them to turn more to roots, tubers, and bark and cambium layers of woody shrubs and trees where they often girdle the plant.

Biology: Meadow mice are primarily diurnal or crepuscular, although they may forage anytime, day or night. They do not hibernate and are active year-round. They frequently tunnel underneath snow in winter; their presence may then be detected by their round burrow openings to the surface.

Predators of voles include coyotes, badgers, weasels, foxes, minks, snakes, hawks, owls, seagulls, herons and probably snakes.

Breeding and young: *Microtus* have substantial reproductive potential. It has been estimated that a single pair of meadow mice could create a population of 3,000 in 8 months if there was no mortality. Some breeding occurs year-round, although the major breeding season occurs in late winter and early spring, coinciding with the peak flush of vegetative growth. Between 5 and 10 litters are produced annually. For *M. californicus*, the average litter size is 4.2, ranging from 1 to 9. Most of the other *Microtus* species average from 5 to 8 young per litter. The gestation period is 21 days, the mother being able to breed again 15 hours after the young are born. The young are weaned at 21 days and are fully independent at 21 days. Sexual maturity is attained at about 4 weeks for females and at 5 to 6 weeks for males.

Population characteristics: *Microtus* populations undergo dramatic fluctuations in abundance. Numerous theories have been advanced to explain the causes of these changes, but as yet there is no wholly satisfactory explanation. Population irruptions in California require favorable climate

providing good summer soil moisture plus a high survival the previous one or two winters. Juveniles and young adults, primarily males, disperse in large numbers during the breeding season, which to some extent is year-round where the climate is mild.

Normal densities of well-established Microtus are probably 100 mice per acre (40 per ha), although peak densities of over 3,000 mice per acre (1,200 per ha) occurred, causing complete destruction of crops and the herbaceous vegetation.

Social organization: Microtus are not highly territorial, although females will defend the immediate vicinity of a nest. Females of M. montanus defend the home range around the burrow against both sexes, except during heat. The home ranges of meadow mice are fairly small, often less than a 50 to 60-foot (15-18 m) radius.

Microtus social behavior has been postulated to play a role in their extreme fluctuations in population size, but intraspecific competition and other social stresses have been shown to be involved in population declines. Much more research is needed into the relationships between social behavior, dispersal, competition, and genetic changes as population regulators in Microtus.

Disease implications: Microtus are believed to play a significant role in carrying plague by acting as a major foci (i.e., reservoir) in some localities, maintaining the organism in pockets of enzootic infection that periodically spread into other hosts (e.g., ground squirrels and wood rats) in an epizootic form. Once in an epizootic form in ground squirrels, chipmunks, or others, the disease is much more readily transmitted to man. Meadow mice rarely infect man directly as Microtus are not highly susceptible to the disease and seldom come into very close contact with humans.

Voles are involved in a wide variety of other known zoonoses. These include adiaspiromycosis, leptospirosis, tularemia, Rocky Mountain spotted fever, Q fever, listeriosis, tsutsugamushi disease, pasteurellosis (hemorrhagic septicemia) and erysipeloid. Most of these diseases are fairly uncommon and are primarily a hazard only to field workers and others frequently exposed to voles or their immediate habitat. Tularemia becomes of concern as a potential human threat primarily when peak populations are reached. Water contamination by infected mice cannot be ruled out.

Economic importance: There are two major types of agricultural and forestry damage caused by microtines in California: 1) damage to field crops and pastures, and 2) damage to orchards and tree plantations. The amount of vegetation these animals consume can be extensive. Some authorities have estimated that a density of approximately 100 mice per acre (40 per ha) can consume 1 ton of green vegetation per year. When one considers that peak densities of 1,000-3,000 mice per acre (400-1,200 per ha) can occur, potential losses can become severe. Because of the gradual, often unnoticed, removal of the vegetation in hay or alfalfa crops, the full magnitude of the loss may not be apparent until it becomes severe.

Direct damage to grain and vegetable crops is generally more obvious but is no less significant. Losses of 50 percent of the annual harvest in grain crops have been reported, and sugar beets infested with Microtus and left for spring harvest can be largely destroyed.

Orchards and tree plantations suffer from a different aspect of microtine damage, namely bark-stripping and girdling of young trees. Meadow mice remove the outer bark and feed on the underlying cambium, which can greatly reduce productivity and growth of the tree if it does not kill it outright. Microtine damage occurs through consumption of broadcast seeds, as well as the clipping and girdling of sprouting or handplanted seedlings.

9. Pocket gophers

Distribution: Pocket gophers (family Geomyidae) are widely distributed throughout California, North America, and south to Panama. They are likely to be present in campgrounds at all elevations in the state. Many subspecies of the Botta's pocket gopher (Thomomys bottae) which is also classified with the southern pocket gopher (T. unbrinus) by some authors, are present at lower elevations in California. In the Sierra Nevada and other mountainous areas in northern California the most likely species will be the mountain pocket gopher (T. monticola). Townsend's pocket gopher (T. townsendii) occurs in the Lassen County area and the northern pocket gopher (T. talpoides) is found in northeastern California. The taxonomy of pocket gophers still suffers from a lack of general consensus by mammalogists, so changes in their classification can be expected in the future, and it may be difficult to know which subspecies is present in any particular campground.

Habitat: Pocket gophers are almost as fossorial as moles. They are found in most soil types, especially those that are light in texture, very porous, and have good drainage, hence permit easy burrowing. They are not found in soils that are continuously wet, in peat, or heavy clay. They commonly occur in high mountain meadows, sparsely in heavily forested areas, abundantly in most rangelands that support herbaceous vegetation, and in most lowland plains and cultivated lands.

Appearance: Pocket gophers have a small somewhat flattened head, short neck but broad muscular shoulders and forearms. Since they spend little time above ground, their eyes are small and protected from soil with close-fitting eyelids. Their tail is short with little hair. A unique adaptation is their mouth. When their furred lips are closed, the incisors still protrude, enabling pocket gophers to cut roots and use their incisors in digging without getting

a mouthful of soil. The life-long replacement growth rate of their incisors is phenomenal; the average annual growth of the lower incisors was measured to be about 14 inches (36 cm) and 9 inches (22.6 cm) for the upper. They also have external fur-lined cheek pouches that can be turned inside-out like pants pockets for emptying contents and cleaning.

Burrows and nests: Pocket gophers individually excavate more soil and construct longer tunnels than any other rodent. Pocket gopher mounds of soil usually appear crescent in shape, unless it is merely a plug in a feeding hole, in contrast to the volcano-like mounds made by moles. Except following irrigation or heavy rains, pocket gophers keep the openings to their burrows sealed when not actively burrowing or feeding. Much of the excavated soil is deposited in abandoned burrows rather than pushing it above ground. When they deposit the discarded soil in snow tunnels, "gopher casts" of soil are formed and these often appear in the spring after the snow melts. The depth of the main burrow systems ranges from about 4 to 12 inches (10-30 cm) underground, depending on soil consistency, but sometimes there are vertical (often spiral) tunnels 18 to 24 inches (46-61 cm) leading to spherical nests of dried grass.

Food: Food is often stored in sealed or unsealed chambers along the shallower main tunnels. Pocket gophers are strict herbivores. They are opportunistic feeders, taking tubers and roots, collecting all the herbage present about feed holes, and feeding on shrubs and other woody vegetation including branches of saplings when they are under snow. Perennial forbs are a preferred food.

Biology: Pocket gophers are active both day and night, often being active for about half an hour and then resting an hour. They do not hibernate in winter. Some summer estivation is suspected but has not been verified. They are extremely intolerant of each other, except for brief periods during the breeding season. Almost invariably if two gophers are put in the same

cage or pen the heaviest animal will kill the other. The home range of pocket gophers is also their individual territory since they defend their entire burrow systems. Dispersal of young is done both above ground and through what may be burrows not belonging to the territory of other pocket gophers.

Pocket gophers are preyed upon by a number of carnivores, raptors, and snakes. Barn owls (Tyto alba) weasels (Mustela sp.), and rattlesnakes (Crotalus sp.) have been shown to be particularly significant predators of pocket gophers. Pocket gophers appear to be most vulnerable to predation when they are pushing soil above ground or when gathering herbaceous vegetation near to a feed hole. But as would be expected, except for in marginal habitats that are unfavorable for pocket gophers, they are more important as prey items to predators than predators are as a controlling factor of gophers.

Breeding and young: Except for in irrigated fields such as alfalfa, most pocket gophers have but one litter of 3 to 6 young, and start breeding in the spring when about 1 year old. Pocket gophers may live 4 or 5 years; old males are much larger than old females because the males continue to grow in body size throughout their lifetimes, whereas females stop growing after their first litter is born. The gestation period is 18 or 19 days, and weaning is thought to occur when the young are 35 to 40 days old.

Population characteristics: Sex ratios of pocket gopher populations have ranged from 1:1 to 1 female to 4 males. Even though pocket gophers are highly territorial, they seem to keep track of their neighbors. For example, in one experiment where a trap was set continuously in the same burrow for two months, a total of 16 individuals was removed. At least four of these animals had traveled at least 23-37 yards (21-34 m) beyond the outer boundary of their territory.

Social organization: It is difficult to know how much plural occupancy of a burrow system may occur in the breeding season, for once an occupant is trapped a neighbor may quickly explore the abandoned system, hence also be captured in the same system. However, multiple catches have resulted in the breeding season when two traps have been set side by side.

Just how pocket gophers communicate with each other is not known. Occasionally in captivity they produce a grinding chatter of teeth, make aspirated sounds in combat, squeals of anger when annoyed, and a vocal expression when bitten by another gopher.

Disease implications: Pocket gophers are not credited with any common zoonoses (transmission of disease to man) or to infecting other animals. They have their share of internal and external parasites, but because of their solitary fossorial habits they do not have much opportunity of transmitting diseases to man, pets, or domestic animals, although some house cats capture many gophers, as do dogs during flood irrigation of an infested alfalfa field.

Economic importance: The constant digging action of pocket gophers in meadows and rangeland may have some benefit in mixing the soil and keeping it more porous. On hillsides it is not unusual to see water channeled by a road or trail enter an open gopher burrow. But this does not mean this water is being stored, for nearly always at such times the shallow soils are already saturated and this water merely reappears downhill in the same burrow system as a small artisian well. The exposure of subsoil and rocks within the burrow to air, water, and solvents may increase weathering of the substrate. Fresh gopher mounds on hillsides are subject to erosion with the next rain. Even though it may be difficult to prove, and that is why there is little such data in the literature, it does seem likely that the great mixing of soils done by pocket gophers and the addition of their wastes and abandoned food carried below ground must have some beneficial effects.

There is no question that large populations of pocket gophers on wild lands can be very instrumental in changing the plant composition. But it is in agricultural areas that pocket gophers can be so destructive of crops and cause washouts of irrigation ditches, and cause excessive erosion. Because of their abundance, pocket gophers may in some areas compete with livestock for forage more than do ground squirrels, and they have been responsible for the failure of many reforestation projects by killing the seedlings and saplings.

Being the principal burrowing rodent, their extensive burrow systems in campgrounds sometimes cause problems of erosion and mild cave-ins of roads. Their mounds create nuisance problems when they appear in trails or in an individual campsite. Abandoned pocket gopher burrows are frequently taken over by other rodents.

10. Moles and shrew-moles

Distribution: There are three species of moles (Scapanus spp.) and one species of shrew-mole (Neurotrichus gibbsii) in California. These do not belong to the Order Rodentia, but belong to the Order Insectivora. Scapanus orarius (Pacific or woods mole) and S. townsendi (Townsend's mole) occur only in a small area along the northwest coast of California. S. latimanus (California or broad-footed mole) is much more widespread, occurring throughout most of the state except in desert regions and the Central Valley. Neurotrichus gibbsii inhabits the coast from Monterey north to Oregon, and inland in the Yolla Bolly, Trinity, Salmon, Shasta and Lassen regions.

Habitat: S. orarius favors meadows and deciduous forests of the Transition Life Zone; S. townsendi is found in fields, lawns, moist meadows and coniferous forests of the Transition Life Zone; S. latimanus inhabits soft or porous soils of valleys and mountain meadows; N. gibbsii occurs in moist areas along streams or in shady ravines where the ground is free of turf, in redwood, Douglas-fir, and yellow pine forests from sea level to 8,000 feet (2,400 m) Transition and Canadian Life Zones.

Appearance: Moles are small, less than 10 inches (25 cm), soft-furred mammals with long partly naked snouts, very small eyes (barely visible), and no visible ears. The forefeet are very large and powerful, adapted for digging or "swimming" through the earth; the tail is short and either naked or lightly haired. The shrew-mole is similar but smaller, with a black body and black hairy tail, narrow forefeet, and nostrils open to the sides.

Burrows and nests: Moles are rarely seen above ground, living most of their lives beneath the surface. Their presence is indicated by the low ridges pushed up as they move just under the ground surface. In the spring after the snow melts, these tunnels are distinct from the castings of pocket gophers. The ridges formed by moles are part of the ground surface pushed up

from below, whereas gopher castings are formed when gophers deposit soil from digging in their abandoned snow tunnels. Moles also create characteristic volcano-shaped mounds of soil that are pushed up from below, with no sign of the burrow entrance. The mounds are excavated coarse or cloddy dirt from deep tunnels. These tunnels may be four feet (1.2 m) deep and are used as nesting sites or when the surface soil becomes too dry. The shallow surface tunnels are 5 or 6 inches (15 cm) deep and are temporary, created by the mole in search of earthworms or other food. Active runways can be detected by pressing down the ridges in various places and observing which have been forced up the next day. The nests of moles are usually in a 6-inch (15 cm) chamber 12 to 18 inches (30-46 cm) below ground and are constructed of grass, small roots and sometimes leaves. The nests of the shrew-mole are found in rotting stumps or logs.

Food: Moles are insectivores, and as such the bulk of their diet is earthworms, sowbugs, and other insects, especially larvae. To a limited extent they may feed on seeds, roots, tubers, bulbs or other plant material.

Biology: Moles are active year-round. The Townsend's mole is fairly nocturnal but the others are equally active by day and night. Moles rarely leave their tunnels except for the shrew-mole, which spends considerable time above ground searching for food (mainly insects).

Moles are highly adapted for a subterranean existence. Their fine, soft fur sheds dirt readily and remains quite clean. Moles have greatly modified skeletal features that equip them for rapidly moving both forward and backwards through burrows. The eyes and ears are almost useless; yet the mole can sense exceedingly slight vibrations transferred through the ground.

Breeding and young: Breeding occurs from about late February through March, the young being born from March to April. The gestation period is 4 weeks. The young are born large and hairless, an average of 4 per litter

(ranging from 2 to 6). One litter is produced per year. The young reach adult size in 2 months.

The shrew-moles breed year-round (except for mid-winter). More than 1 litter is produced per year, consisting of 1 to 4 young.

Social organization: Moles are solitary and often will fight fiercely on meeting one another. They are territorial and will drive other moles out of a burrow, although they may use common runways, as under fence rows, to get to different areas. As many as 20 to 30 moles may be trapped using such runways.

Disease implications: Moles are of almost no public health significance. They may rarely carry diseases such as adiaspiromycosis or schistosomiasis, but these are seldom if ever communicated to man from moles.

Economic importance: Lawns, gardens, and golf courses may be damaged by mole hills and tunnels. Their mounds foul machinery used to harvest hay. Some moles may eat tubers, bulbs, and roots of garden plants. A single mole can make 200 to 500 mounds during the rainy season from October to April.

C. Rodent-borne Diseases

Some of the more important rodent-borne diseases which may be associated with campgrounds and recreational sites are discussed in some detail. These include plague, Rocky Mountain spotted fever, leptospirosis, salmonella, and tularemia. Since the amount of information available on these diseases is voluminous, only the highlights are covered here. Rabies, as well as some other less common diseases are not discussed. Our reason for excluding rabies is that it rarely occurs in rodents, although it may be found in such animals as skunks, foxes, coyotes, raccoons, and bats. When rabies outbreaks occur in close proximity to human populations and their pets and livestock, the infected species are usually controlled by trap or poisons to prevent serious human involvement, although the disease eventually will run its course with most of the infected animals dying out. Once rabies is found in wild animals of an area, the disease will recur from time to time.

In campgrounds where plague has been encountered or suspected in previous years, it is highly desirable to put up plague warning notices, as is currently done.

1. Plague

Plague is caused by the bacterium Yersinia pestis. It is a highly infectious bacterial disease, primarily found in wild (sylvatic) rodents (deer mice, meadow mice, ground squirrels, chipmunks, wood rats, rabbits, and others), causing varying degrees of mortality. Carnivores which feed on infected sick or dead mammals may also become infected. Plague becomes a public health threat when humans enter areas where a plague epizootic is in progress or in urban areas when the disease transfers from wild rodents to the introduced Old World rats that live in close association with humans. Human cases occur almost every year in California, mostly the result of being bitten by infected fleas from ground squirrels or chipmunks. Plague cases in humans have been increasing in the last decade.

Plague is an ancient disease that has severely affected man, especially during three worldwide epidemics or pandemics. The first, The Plague of Justinian, probably began in Africa and was first recorded in 541 A.D. in Egypt. Plague entered Constantinople, the capital of the Eastern Roman Empire, and from there spread westward across Europe. It killed millions, depopulating towns and whole regions. Ourbreaks continued for 50-60 years before the disease abruptly disappeared. In 1348, Genoese traders returning from the east introduced it into Italy. With tremendous speed, plague spread throughout Europe, killing at least one-third of the population. Local epidemics continued for 400 years, one of the worst being The Great Plague of London in 1664, which took 100,000 lives. The third pandemic, called The Modern Plague, started in Asia in the 1850s and lasted for 100 years. Most of the world was affected. India was especially hard hit with at least 13 million fatalities. While plague may have been previously present in

America, it also was introduced at this time, creating a new known region of permanent plague in the western United States.

In June 1899 the ship S.S. Nippon Maru, carrying plague-infected rats and two infected humans, arrived in San Francisco from Hong Kong. The ship was quarantined and no apparent spread of disease occurred. However, infected rats probably did come ashore, because 8 months later plague broke out in San Francisco. The epidemic lasted 5 years with 126 cases reported and 122 deaths. The disease appeared again in San Francisco one year after the great earthquake of 1906. During the outbreak 191 cases resulted in 94 deaths. In 1924 a third major outbreak occurred in Los Angeles with 41 cases and 36 deaths. This was the last large urban plague outbreak in the United States. Plague in native wild rodents and rabbits spread relatively rapidly and by 1950 it was recorded in 15 western states, covering approximately 40% of continental United States. Currently plague is found from the Pacific Ocean east to Kansas and Texas, and also in parts of Mexico and Canada.

Plague is most commonly transmitted in California from rodents to man via the flea. For example, when a bloodsucking flea bites an infected ground squirrel, it ingests plague bacteria. The bacteria multiply in the flea's forestomach (proventriculus) and eventually the forestomach becomes blocked by the mass of bacteria, making the flea unable to swallow and digest more blood. In an attempt to obtain food, the starving flea bites repeatedly. Each time the flea bites, blood enters the esophagus, is blocked by the bacteria, and surges back to the victim carrying thousands of plague bacteria. When infected squirrels die, their infected fleas move to other hosts, which may be another squirrel, a different wild animal, or a human. the new host, providing it is susceptible to plague, becomes infected and continues the cycle.

It is important to mention that even though plague may be found in native rodents covering a wide geographic area, in many of the states where plague is found humans are apparently at little risk because different species of fleas are involved or the vector fleas are few in number. Some species of fleas rarely bite man even when he is available. California and some of the other western states seem to have a relatively ideal combination of factors conducive to plague risks in humans because they have suitable rodents to serve as the reservoir of plague and also highly susceptible rodents (i.e., ground squirrels) with which man comes into relatively close contact and which often support high populations of fleas that bite man when the opportunity prevails.

One route of infection, at least among wild animals, is through feeding on other infected animals (predation). People can become infected also by handling diseased animals and inadvertently taking in bacteria from the animal's body fluids through cuts and abrasions, or by eating undercooked infected meat.

The most contagious and dreaded form of plague is the pneumonic form which involves the lungs and is transmitted from animal to humans or from humans to humans by airborne bacteria. Late stages of bubonic plague may develop into the pneumonic form.

Plague may take three forms in people: bubonic, septicemic, or pneumonic. The most common form, bubonic plague, spreads through the body via the lymph system. It is characterized by swollen lymph glands, or buboes. Other symptoms may include a high fever up to 106°F (41°C), headache, and nausea. Initial symptoms usually appear 2 to 6 days (but up to 10 days) after infection (e.g., a flea bite). Septicemia plague, a relatively rare form, enters the bloodstream directly and spreads through

the body. The bacteria multiply rapidly, resulting in internal hemorrhaging and swelling of the liver and spleen. The pneumonic form, which caused one fatality near Lake Tahoe in 1980, is centered in the lungs and is highly contagious. Of the three, it is the most dangerous to humans. Plague bacteria develop in the lungs so rapidly there may be no time for usual symptoms of bubonic plague to appear. Within 1 day from infection, signs of bubonic plague appear. Within 1 day from infection, signs of a generalized infection such as headache and fever may appear. By the second or third day, coughing, blood in the sputum, and respiratory distress clearly indicate lung involvement. Death may occur 2 to 4 days after infection.

The dangers of an epidemic of the highly contagious pneumonic form of plague being spread from one person to another is probably greater today than at any previous time in the country's history. Reservoir and susceptible rodents are numerous in our recreational areas, more people than ever are spending leisure time in the out-of-doors, urban and suburban densities of people are increasing, and rapid transportation enables vast numbers of people to move great distances in a short period of time. It is now possible with air travel for a single infected person to infect hundreds of people in several major cities across the country in a matter of hours. These people could in turn infect others and, in spite of all we know about plague, the disease could be epidemic in a matter of days or a few weeks at most. Before it could be checked, thousands could die.

Plague is treatable with prompt diagnosis and administration of specific antibiotics, but if the doctor does not know the patient may have been in contact with rodents or rabbits, he may not be able to make a proper diagnosis before the disease has progressed too far. Rapid and proper diagnosis

is essential for both the patient and, in the case of pneumonic, the safety of those who may have come in close contact with the patient. In spite of effective antibiotics, treatment is often too late and fatalities remain relatively high in plague cases.

Factors important to understanding the epidemiology of plague are as follows:

1. The persistent reservoirs of plague are not those species implicated in epizootics, but are relatively resistant ones (e.g., meadow mice and deer mice) in which the disease may remain in a latent state.

2. Enzootic plague persists in foci or pockets. Such foci characteristically are in relatively cold upland sites (e.g., coastal foothills, Sierra Nevada).

3. Epizootics occur when infection transfers to susceptible species (e.g., ground squirrels, chipmunks, etc.) of relatively high density.

4. High densities of susceptible populations (i.e., ground squirrels or chipmunks) coupled with an adequately high flea index is a prerequisite of epizootics.

5. Ongoing epizootics present plague risks to humans who frequent the area where the infected rodent and its fleas exist.

6. The most important public health threat is not the sporadic cases of plague contracted from infected fleas or directly from handling infected rodents, but the potential danger of an epidemic or pandemic resulting from the pneumonic form of plague being transmitted from person to person.

2. Rocky Mountain spotted fever

Rocky Mountain spotted fever (RMSF) is a zoonosis caused by rickettsia, which are small bacteria-like microorganisms typically adapted to intracellular parasitism of arthropods. The rickettsia involved are generally around 0.5 microns in diameter and occur in the nucleus as well as the cytoplasm of host cells. The organism cannot be cultivated in media without the presence of living cells, and cannot withstand dessication, disinfectants, or temperatures of 122°F (50°C) for 10 minutes.

The disease is an acute, severe infection of the blood vessels and is characterized by a high fever and a spotted rash appearing first on the wrists and ankles. Without antibiotic treatment, the mortality rate for RMSF averages 20%, but may be as low as 3% or as high as 75% depending on the geographic area, age of victim, and other factors. The use of antibiotics has now greatly reduced the fatality rate.

Rocky Mountain spotted fever is transmitted by tick contact. The rickettsia are present in the saliva and other tissues of the tick, so infection can occur from the bite, from contamination of the bite wound with tick feces, or through crushing of ticks on the skin. Ticks acquire the organism by feeding on an infected host. Once infected, a tick retains the rickettsia for life and commonly transmits the disease to successive generations through transovarian passage. Ticks of the family Ixodidae are the primary arthropod vectors. In the United States, Dermacentor andersoni (Western wood tick) and D. variabilis (Eastern dog tick) are responsible for the majority of human cases. The rabbit tick, Haemaphysalis leporispalustris, does not ordinarily feed on man but plays a critical role in disseminating and maintaining the disease in wild animals. The rabbit tick has a wide distribution and variety of hosts, as well as occurring in tremendous numbers under certain conditions. Other species of ticks may also be natural reservoirs of Rocky Mountain spotted fever.

In a typical life cycle of Dermacentor spp., the eggs hatch into six-legged larvae and locate a host, usually a small rodent. During a 4 to 6-day period the larvae feed to engorgement and then detach. After moulting into 8-legged nymphs they seek another host and engorge themselves over a 6 to 8-day period. The nymphs then detach and moult into male or female 8-legged adults. The adults must find a third host and feed to engorgement (usually 7 to 10 days) before the eggs are produced. After detaching, the female lays 2,000 to 6,000 eggs and dies without feeding again. Adult ticks can survive up to 4 years without feeding. The whole cycle from adult-to-adult probably takes about 2 years to complete under natural conditions.

Animal hosts play an important role in the maintenance of the disease, as they are the ultimate source of tick infection. A great variety of wild rodents are hosts to RMSF, including meadow mice, deer mice, ground squirrels, chipmunks, rats, and house mice. In addition, lagomorphs, deer, canids, birds, and many other wild animals are involved in the transmission of the disease.

The geographic distribution of RMSF is uneven, the majority of cases occurring in the middle and southern Atlantic seabord as well as the states around the Rockies and the northwest. Washington, California, and Nevada have comparatively few cases, however. In addition, the incidence of RMSF varies seasonally, as the epidemiology of the disease is dependent on the life history of the tick vectors. Most cases occur during late spring and early summer with occasional cases later in the summer. The disease primarily afflicts those whose occupations or recreational activities expose them to contact with ticks. Thus one finds it among campers, picnickers, hikers, hunters, foresters, surveyors, sheepherders, agricultural workers, and the like. Occasionally pet owners have acquired infections when removing ticks from their dogs.

In wild rodents, RMSF often produces symptoms such as listlessness, progressive loss of weight, high fever, enlarged spleen, and characteristic scrotal involvement entailing a spotted rash followed by necrosis and sloughing of the scrotal skin. Necrosis of the ears may also be present. Virulant strains can cause death within the first week.

In man the disease has an incubation period of from 2 to 12 days, averaging about 6 days. Before the definitive symptoms appear, there are usually a few days of vague illness, headache, loss of appetite, body aches, and chills. The actual onset is sudden with severe chills and a high fever of 104°F (40°C) or more, weakness, sore muscles and joints, painful and tender extremities, severe headache, and sometimes nosebleed or a dry cough. A deep red or purplish spotted rash appears first on the ankles and wrists and spreads rapidly to the back, arms, legs, chest and finally to the abdomen. Severe illness may persist for 2 weeks or so. Complications involving the central nervous system, genito-urinary system, or the cardiovascular system can occur, as well as peripheral gangrene due to vascular and perivascular inflammation.

Numerous methods are available for the laboratory diagnosis of RMSF, although they are useful mainly for epidemiologic and public health diagnoses rather than of direct value to the patient. Isolation of the organism by culturing in live guinea pigs, embryonated hens' eggs, or in tissue suspensions is possible though time-consuming. Various serologic tests are also available such as agglutination procedures, the CF test, hemagglutination, the fluorescent antibody test, and several others based on toxin neutralization or precipitin reactions.

The treatment of RMSF is with certain broad-spectrum antibiotics. Early antibiotic treatment greatly reduces the fatality rate of the disease.

Prevention of RMSF includes the avoidance of endemic tick-infested areas, wearing of clothing that will reduce the likelihood of tick bites, and the use of chemical repellents. Since Ixodid ticks spend a fair amount of time crawling around and are slow to attach, twice daily examination of the body is of great value. Usually a period of several hours' feeding is necessary for infection to occur from the tick bite. If ticks are found on the person or on pets, they should not be crushed or removed with the bare hands. Ticks should be removed carefully to avoid leaving the mouth parts in the skin. For people that are continually exposed, vaccination is possible. Two or three innoculations provide immunity for about one season, but the effect is not permanent. Tick control with effective insecticides may be warranted in some habitats such as around cabins. Insecticides applied directly on pets may also offer some protection.

Reduction of rodent populations may be useful in limited areas but is not effective in controlling the disease on a large scale. Dipping of livestock to remove adult ticks is also helpful. Habitat modification by grazing, clearing brush or by burning over tick-infested areas can greatly reduce some kinds of rodents and tick populations but may be undesirable for other reasons and of short-term value if not continued. Direct applications of insecticides are not acceptable over large areas, but limited use along trails and walkways may achieve control as ticks concentrate in these areas. Apparently ticks congregate along animal paths to facilitate finding a host, and the use of appropriate insecticides in limited areas may be effective and environmentally acceptable. When hiking along deer trails, avoid having overhanging vegetation touch your head or body.

3. Leptospirosis. Other names: Weil's disease, mud fever, swineherd's disease, rice-field fever, autumn fever, seven-day fever, Canicola fever.

Leptospirosis is caused by spirochetes of the genus Leptospira. It is actually a group of diseases caused by antigenically different species (serotypes) within the genus. As a result the disease may vary from inapparent to fatal depending on the serotype and host involved. The causal agent is a small, spiral-shaped, actively motile organism between 3 to 30 microns long and 0.06 to 0.12 microns wide. They are visible only with dark field microscopy and are difficult to stain or cultivate in vitro. They cannot withstand high salinity, dessication, heat, disinfectants, or pH above 8 or below 6.

Transmission usually involves urine containing leptospires, which are excreted by the carrier animal into moist soil, stagnant ponds, or slow-moving streams. Leptospiral organisms can survive for several weeks if such environments are slightly alkaline and do not dry out. Transmission to man or other animals occurs through direct contact of the urine or organs of infected animals, as well as through contacting contaminated mud, water, crops, or moist soil. Leptospires enter the body through the mucous membranes of the eye, nose, or mouth and through broken or abraded skin.

Natural reservoirs of leptospirosis include beavers, Norway rats, roof rats, house mice, meadow mice, and other field rodents. Leptospirosis is cosmopolitan in its geographic distribution, being found throughout North America. It is most common in warmer, humid or wet climates and is comparatively rare in dry, hot or very cold environments such as mountains and deserts. There may be seasonal changes in the incidence of leptospirosis, as the time of year can affect the soil humidity, ambient temperature, surface water supplies, animal behavior, and other factors critical to the

transference of the disease. The relationship is not a simple one, however. Crowding together of animals, unusual weather conditions or other changes in the environment can allow leptospires to proliferate in habitats (or at times of the year) in which they are usually not a problem.

Not very much is known about the clinical symptoms in wild animals. Rats and smaller field rodents seem to be highly susceptible to infections, develop nephritis (i.e., kidney infections), and shed large numbers of leptospira in their urine and yet may show few or no overt signs of the disease. Depending on the species concerned, they may harbor the organism for only a short while and then recover or they may continue to shed leptospira in their urine throughout their lives.

The disease in mammals is typically hemolytic anemia with subsequent renal and liver involvement. Complications include foetal abortion, encephalitis, and temporary meningitis, as well as ocular infections. Massive nephritis leading to uremia is the cause of death in many severe cases.

In man the symptoms are fever, headache, photophobia, vomiting, weakness, loss of appetite, muscle aches, conjunctivitis, meningitis, hematuria, or hemoglobinuria. Jaundice and renal failure occur in severe cases. The incubation period is from 1 to 2 weeks with a sudden onset of fever, often accompanied by chills. The first attack of fever lasts 3 to 6 days and is followed by 8 to 10 days without fever, after which there is a relapse of a milder fever. Insomnia, depression, or irritability may also occur. Because there are more than 100 different serotypes or forms of the disease, the severity of human leptospirosis varies from mild to fatal.

Leptospirosis may be diagnosed by demonstration, serology, or bacteriologic methods. Demonstration techniques are not very reliable as the organism is not readily visible through microscopy. Serologic tests such as the

microscopic and macroscopic agglutination tests or the fluorescent antibody procedure are fairly reliable. Unfortunately, antibodies do not begin to show up in the host until the second week of the disease which prevents an early diagnosis. For animal studies, however, this may be acceptable. It should be noted that antibodies can remain in the host for at least 2 years, leading to possible erroneous diagnosis.

Bacteriologic methods involve the direct culture or animal innoculation of leptospires in tissue or fluid samples from the host. When performed properly, culture methods are as sensitive and reliable as innoculation of laboratory animals as a diagnostic technique.

Treatment with antibiotics is of some usefulness, although it is most effective in the early septicemic stages of the disease (usually before symptoms appear and treatment is sought). Once the leptospira have spread, antibiotics seem to have little effect on the clinical course of the disease. Treatment other than antibiotic should be adjusted to the organ systems involved and to the severity of the symptoms.

Prevention of leptospirosis involves improving sanitation and avoiding contaminated areas. Moist soil, stagnant water or other habitat harboring the organisms can be drained or avoided. Where this is not possible, workers on irrigated or flooded fields should use rubber shoes and gloves, and avoid direct contact with contaminated water and mud. The control of rodents from fields, sheds or pastures is recommended where there is a known or suspected risk of leptospirosis. Contaminated drinking water can be treated before use.

9. Relapsing fever

The relapsing fevers are a series of related infectious diseases caused by spirochetes of the genus Borrelia. The disease is characterized by chills and a high fever that disappear, then reappear after a week or so, sometimes relapsing in this matter up to 14 times.

Transmission is due to arthropod vectors, either by means of the human body louse or the head louse, or by ticks of the family Argasidae. Apparently the human lice (Pediculus humanus corporis and P. humanus humanus) cannot transmit the disease during feeding but rather must be crushed. Such transmission is responsible for the epidemic form of the disease. It appears that man is the only reservoir for this form, as transovarial passage in the louse has not been demonstrated.

Argasid ticks, on the other hand, are implicated in the endemic forms of relapsing fever. Within the family Argasidae there are some 70 species, of which little is known regarding their role in the maintenance of the disease. At least 14 species have been shown to be vectors, however. In California Ornithodoros turicata and O. hermsi are the primary tick vectors, with O. parkeri and O. talaje perhaps being involved as well.

Tick transmission can occur through feeding (i.e., through salivary gland secretion), by excretion from the malpighian tubules, and by the excretion of coxal fluid during the feeding process. Ticks can transmit the spirochetes to successive generations by transovarial passage, although the effectiveness can vary from zero to 100% transmission depending on the species. Ticks acquire the spirochetes by feeding on infected animals, but it is not known which small animals and rodent species are involved. Wood rats (Neotoma spp.) and kangaroo rats (Dipodomys spp.) have been shown to carry the disease in the United States. Spirochetes have also been recovered

from commensal rats (Rattus spp.), chipmunks, tree squirrels, and some native mice. Ticks are responsible for the maintenance of the endemic disease in these animals. The spirochetes often survive throughout the life-span of the tick host, which may be as long as 12 years. The epidemic spread of the disease is due to lice in which the survival of the spirochetes is fairly short.

Relapsing fever is found throughout the world on all continents except Australia. It occurs in much of the western United States, including California. The seasonal prevalence of the disease depends on the ecology of the vector; the louse-borne forms are most common in winter and spring, and the tick-borne forms are predominant in summer. In California most cases occur during June, July and August. The disease afflicts both sexes, although males seem to be more often infected by tick-borne relapsing fever. All ages are susceptible.

In rodents, the severity of relapsing fever may vary from minor to fatal depending on the strain of spirochete and the method of infection. After an incubation period of about 3 to 8 days, there is a fever that relapses periodically. The spirochetes appear in the blood stream during each relapse. However, the disease may produce no visible symptoms although spirochetes are present, and the disease may be of a continuous rather than relapsing type.

In man, a 4 to 9-day incubation period is followed by a sudden onset of acute chills and high fever. Profuse sweating occurs with frontal headache and intense pains in the back, limbs and joints. A spotted rash may be present. Neurologic symptoms such as impairment of vision or hearing or a generalized peripheral neuritis may occur. The patient returns to normal for a week or so, after which 1 to 14 more relapses can occur. Diagnosis is through detection of spirochetes in the peripheral blood supply. Characteristic changes in the spleen are indicative in fatal cases.

Historically, relapsing fever has been treated with arsenical agents. More recently antibiotics such as aureomycin, terramycin or streptomycin have been used.

Prevention of relapsing fever involves the avoidance of ticks and lice. However, the avoidance of ticks is not as simple as for the diseases transmitted by Ixodid ticks. Argasid ticks engorge and detach within a few minutes rather than over several days and one does not feel their bite. Some species may transmit the disease within 30 seconds after attachment. Thus it is important to destroy the ticks in their habitat (where possible) if they are endemic and avoid entering such areas. Chemical repellents applied to clothing may be of value to persons whose recreational or occupational activities expose them to tick habitats. It should be remembered that caves are also inhabited by certain ticks capable of transmitting relapsing fever. Contact with wild rodents should also be avoided or minimized if possible.

5. Salmonelloses. Other names: Salmonella infections, food poisoning, typhoid fever and paratyphoid fevers.

Bacteria of the genus Salmonella are responsible for pathogenic infections in a wide variety of animals as well as man. Food poisoning in humans is also commonly due to Salmonella. Within the genus, Salmonella are classified by serotype, over 700 serologically different types being recognized. As a result, Salmonella give rise to a great variety of clinical syndromes of differing severity. All types seem to be pathogenic for man.

Infections of Salmonella are most commonly due to ingestion of the organism in contaminated food or liquids. Food may be contaminated by improper storage after preparation; or, if of animal origin, the food may harbor the bacteria prior to preparation. Meat products, especially pork and poultry, milk, eggs, and related foods may cause infections when rendered, handled, and improperly cooked or stored. Salmonella infections may also be contracted from domestic animals (such as dogs and cats) as well as from many wild animals. Salmonella may be transmitted by wild rodents where their feces can come into contact with man or his foodstuffs. Rats and mice are frequently carriers of salmonellae and excrete the bacteria in their feces where it may continue to be infective for months. Transmission may also occur through arthropods, although this is probably uncommon. More rarely, infections from inhalation of Salmonella containing dust or droplets can occur.

Salmonellae are widespread and naturally occupy the intestinal tract of humans, mammals, birds, and reptiles. Most infections are gastro-intestinal in nature, although the bacteria can cause symptoms ranging from localized abscesses to severe systemic disease. It is usually necessary to ingest or contact large numbers of salmonellae before human infection occurs. Some types of Salmonella are specifically pathogenic to man in small quantities,

but most types require millions of organisms to produce illness. The bacteria must be alive as well, since Salmonella food poisoning is due to infection. Since they produce an endotoxin that is stable at high temperatures, a temporary poisoning may occur even though an active infection was prevented by cooking.

California has an average proportional incidence of the disease, although this amounts to a large number of cases due to the high human population of the state. In 1967 over 2,000 cases were reported in California. In addition to the differences in Salmonella incidence between states, one finds that the serotypes involved vary geographically. In any given state, certain serotypes will be more often encountered than in other areas. Salmonella infections also show a seasonal pattern, most cases occurring during the warm summer months.

The clinical symptoms of Salmonella infection are usually an intestinal inflammation (gastroenteritis) which may spread to a more generalized systemic involvement. In wild rodents diarrhea is common followed by systemic septicemia that is often fatal within 24 hours. Epizootics also occur in rodents, and survivors may become carriers that continue to excrete the bacteria in their feces. In man 4 types of clinical syndromes are common.

The typhoid form involves severe and persistent systemic symptoms resembling those of typhoid fever. An acute onset may occur, but more often there is a long incubation period (about 10 days). This is followed by symptoms such as headache, joint and back pains, constipation or diarrhea (without blood), abdominal discomfort, mild vomiting, loss of appetite, and a slight cough. Contact infections can transmit the disease from man to man, and chronic Salmonella carriers often result. This form of the disease is normally not due to a zoonosis (animal to man) but rather arises from Salmonella strains that are specifically adapted to man.

The gastroenteritic form has a shorter incubation period (about 12 hours) and less persistent symptoms (1 to 4 days). The disease is usually confined to the gastrointestinal tract, resulting in diarrhea, vomiting, headache, abdominal pain, and a slightly elevated temperature. Dehydration and electrolyte imbalance may occur. Contact infections are infrequent and carriers excrete salmonellae for only a few weeks. This form of infection is most often due to salmonellae of animal origin.

The third type of infection results in temporary or chronic carriers that show little or no clinical symptoms. Such individuals continue to excrete salmonellae and may be instrumental in further transmission of the disease, especially if they handle foodstuffs. The carrier form of infection can be due to salmonellae of either human or animal origin.

Finally, the disease may take the form of abscesses or localized infections of the skin, bone marrow, joints, pleural cavity, testicles, gall bladder and meninges. Various types of salmonellae are responsible.

In addition to the clinical symptoms, diagnosis may be performed by examination of blood, urine, and stools. Blood or stool cultures are among the more reliable diagnostic procedures. Microscopy of blood and stools is valuable, and urine analysis and agglutination tests are useful in some cases, although they should be interpreted with caution. It is important to obtain the recent history of the patient in order to trace the source of the infection. Care should be taken to distinguish Salmonella infections from similar syndromes such as botulism or staphylocci. Food infections, dysentery, malaria, influenza, typhus and other rickettsioses such as Q fever or Rocky Mountain spotted fever, tuberculosis, brucellosis, and other bacteremias and septicemias. Once isolated, the 700 or so individual strains of Salmonella are distinguished by various serologic and biochemical tests.

Salmonella infections are treated with antibiotics, although resistance of Salmonella to certain antibiotics has occurred. Mortality from most Salmonella infections is low, about 1%.

Prevention of the disease involves proper hygiene such as washing hands before preparing food and after handling animals, their hides or their meat. Proper cold storage of fish, meat, milk, eggs, and dairy products is critical in preventing the growth of salmonellae. Fresh water does not support the growth of large numbers of the bacteria, but contaminated water and liquids such as milk provide an excellent growth medium. Suspect water must be treated and milk should be pasteurized and kept at low temperatures. Rodent control or exclusion is necessary wherever they may contaminate foodstuffs or where their feces may come into contact with man or domestic animals. It is also important to detect human carriers, especially when the possibility of food contamination exists. Such persons should not be allowed to prepare food.

The lack of good refrigeration of foods contributes to Salmonella problems with campers and picnickers because once the food is contaminated, the bacteria can multiply rapidly in certain unrefrigerated foods. In campgrounds rodents and other animals should be prevented from contaminating foods by proper food storage. Tabletops and other food preparation or serving surfaces exposed to rodents and the elements should be thoroughly washed with soap and water prior to their use. This will also greatly reduce the chances of contracting leptospirosis.

6. Tularemia. Other names: rabbit fever, deer-fly fever, Pahvant Valley plague, Chaga's disease.

Tularemia is an acute septicemia caused by Pasteurella tularensis. The bacteria involved is easily destroyed by temperatures of 133-136°F (56-58°C) within 10 minutes, so infected tissue is harmless after cooking. The organism is also killed by germicides such as Lysol or Cresol, or by exposure to sunlight for 3 hours. P. tularensis survives many months and even years in humid soil, water, wheat grain, laboratory cultures, frozen tissues, and insect vectors.

The bacteria enters the bloodstream through the bite of an infected arthropod vector and less frequently by the bite of an infected mammal. Ingestion or handling of the flesh or hide of an infected animal, contact with contaminated water, inhalation of dust from contaminated wheat or hay, and a wide variety of other routes of infection are possible. Transmission through unbroken skin can occur. Considering that tularemia probably has more different modes of transmission and natural reservoirs than any other infectious disease, it is surprising that the disease is not more common in man.

Lagomorphs and rodents are the main hosts to both enzootic and epizootic infections of tularemia. In California tularemia has been found in deer mice, meadow mice, marmots, Norway rats, wood rats, and ground squirrels. It is probably also present in chipmunks, tree squirrels, pocket gophers, kangaroo rats, porcupines, moles, beaver, house mice, and various other native mice. Arthropod vectors include mites, ticks, fleas, flies, midges, mosquitos, and lice.

Tularemia occurs throughout most of the United States, with the central and southeastern states having the highest incidence of the disease. It has also been reported in many other countries. Most cases in the western states

occur in summer, peaking from March to June due to a seasonal increase in wood ticks, and again from July to September due to the increase in deer flies. Infections from handling jackrabbit carcasses are most common between April and October. Likewise infections derived from skinning cottontail rabbits reach their maximum during the hunting season. The number of cases of tularemia in California has been lower than much of the United States, averaging about 12 cases per year between 1924 and 1960.

Very little is known regarding the clinical signs of tularemia in wild rodent populations. Infected rabbits and hares behave oddly, have poor muscular coordination, and appear to be tame or in a stupor. They often show no fear of natural enemies or man. There may be respiratory symptoms such as coughing or labored breathing. A rise in body temperature and local swelling of the lymph nodes is common. Diarrhea occurs in many advanced cases. Gross pathological and histological symptoms resemble those of plague or pseudotuberculosis. The lymph glands and liver are enlarged, as is the spleen, which may be 3 to 4 times its normal size, and all show grayish-white spots ranging from the size of a pinpoint to several millimeters in diameter. The lungs and bone marrow may also have small spots. Thromboses of small blood vessels frequently occur, and the skin is usually necrotic around the insect bite or point of entry of the infection.

In man tularemia is classified into 5 clinical types. All are characterized by a sudden onset after an incubation period of 3 to 4 days (ranging from 1 to 10). Symptoms include chills, general weakness, fever, loss of appetite, aches and pains in muscles, joints, and various other parts of the body, headache, and vomiting. A sore at the site of initial entrance of the bacteria develops, with swelling of the associated lymph nodes. Flushing of the face and conjunctivitis may occur. The tongue is coated and dry.

During the first few days the body temperature rises to 100-102°F (38-39°C) and fever is usually remittent. There may be a remission of fever and some improvement after 3 days, followed by a renewed fever lasting for 3 to 4 weeks, after which it gradually subsides. Convalescence is slow and protracted, requiring 2 to 3 months. After recovery a solid immunity against reinfection exists, and even under occupational exposure such persons will rarely experience a second attack.

Diagnosis can be made by live culture of P. tularensis from samples of sputum, lesions, or pleural fluid from the patient. Alternatively, animal innoculation of guinea pigs or mice with such samples is possible. Both techniques are time-consuming and complicated and require laboratory personnel to handle highly virulent live cultures. Serologic tests such as the Ascoli or thermoprecipitin test are simple and more applicable to field studies. This test is valuable as it can be applied to badly decomposed carcasses found during or after an epizootic. The hemagglutination test is useful for early human diagnosis as well as the testing of live animals in epizootics and is capable of detecting the disease sooner than the agglutination tests. Antigen and antiserum intradermal tests are also of value in human and epizootic diagnoses. Care should be used in the interpretation of test results as antibodies against tularemia remain present for many years and a positive reaction may indicate only an old infection. Cross-agglutination with Brucella is likely to occur and can lead to erroneous diagnoses if not controlled for.

Tularemia is effectively treated with antibiotics, and the use of such antibiotics has dropped the fatality rate to below 2% in the United States. Because of the wide variety of hosts and vectors, the disease cannot be eradicated or effectively controlled through large-scale reduction of insect

vectors or rabbit or rodent populations. Rodent, rabbit and ectoparasite control on a very local basis may be indicated when epizootic outbreaks pose a significant risk of transmission to man. Other types of prevention include adequately cooking infected meat, sterilizing or avoiding contaminated water, avoidance of flies and ticks in endemic areas, and vaccination of occupationally exposed persons. For rabbit hunters the wearing of rubber gloves when handling and skinning potentially infected animals is a must. It is important to avoid eating, drinking or smoking in the course of dressing out game which may be infected, and one's hands should be subsequently washed as well. Care should be taken not to wipe the eyes or spatter blood or excreta into the eyes.

The disease is almost never transmitted directly from man to man.

D. Rodent and Other Wildlife Problems in Campgrounds

1. Diseases transmissible to man: Important rodent-borne diseases associated with campgrounds have been discussed individually in the previous section. Table 1 lists the various native rodent and rabbit species from which laboratory-confirmed evidence of plague has been detected repeatedly in California. Information concerning human plague cases in California from 1970-1979, presented in Table 2, clearly illustrates the importance of campground rodent species.

2. Rodent and other animal bites: Being bitten may be the direct consequence of feeding or attempting to feed rodents. It is not uncommon, especially for children, to be bitten while feeding chipmunks, ground squirrels, or tree squirrels. It is thought that most such bites are never reported or brought to the attention of the campground ranger; thus the exact frequency of such bites remains unknown. The chances of being bitten are greatly increased when an attempt is made to hand-catch or trap the animal as children often will do.

The health risks vary considerably depending on the animal, the diseases it may carry, and the severity of the bite. The disease that most often comes to the mind of a parent of a bitten child is rabies. Fortunately rabies is rare in rodents. Probably the greatest danger from such a bite is tetanus.

Tetanus is an anaerobic spore-bearing organism. The spores of this bacillus are present in the soil almost everywhere but especially abundant in animal feces. The natural habitat of the tetanus is the intestine of herbivorous animals (horses and cows). Tetanus enters man and animals through the broken skin such as wounds resulting from animal bites, scratches, and especially puncture-type wounds such as might result from stepping on a board containing a rusty nail.

Preventive measures in the form of inoculation against tetanus is the chief method used in protecting man. Bite wounds from wild animals should be attended

Table 1. Species and genera of rodents and rabbits from which laboratory-confirmed evidence of *Yersinia pestis* has been detected repeatedly in California. Those with an asterisk (*), or their fleas, have been associated with human cases in California.**

Common name	Scientific name
Marmot	*Marmota flaviventris**
California ground squirrel	*Spermophilus beecheyi**
Belding's ground squirrel	*Spermophilus beldingi*
Golden-mantled ground squirrel	*Spermophilus lateralis**
Yellow-pine chipmunk	*Eutamias amoenus**
Merriam's chipmunk	*Eutamias merriami*
Long-eared chipmunk	*Eutamias quadrimaculatus*
Lodgepole chipmunk	*Eutamias speciosus**
Townsend's chipmunk	*Eutamias townsendii**
Douglas' squirrel	*Tamiasciurus douglasii*
Bushy-tailed woodrat	*Neotoma cinerea*
Dusky-footed woodrat	*Neotoma fuscipes**
Deer mouse	*Peromyscus maniculatus*
Piñon mouse	*Peromyscus truei*
California vole	*Microtus californicus*
Montane vole	*Microtus montanus*
Rabbits	*Sylvilagus* spp.
Hares	*Lepus* spp.

**After Nelson, B.C. 1980. Plague studies in California--The roles of various species of sylvatic rodents. Proc. Vertebrate Pest Conf. (J. P. Clark, ed.), Fresno, Calif., March 4-6, 1980. pp. 89-96.

Table 2. The human cases of plague in California in the 1970s with the probable sylvatic rodent source of each infection.*

Case	Year	Sex	Age	Probably animal source and site of infection	Location of Exposure	Location of Diagnosis	Outcome
1	1970	M	8	California ground squirrel, recreational area.	Shasta Co.	Alameda Co.	Recovered
2	1970	M	45	Chipmunk, home area.	Plumas Co.	Plumas Co.	Recovered
3	1970	F	10	California ground squirrel, recreational area.	Kern Co.	Kern Co.	Recovered
4	1975	F	1 1/2	California ground squirrel, home area.	Ventura Co.	Ventura Co.	Fatal
5	1975	M	14	Rock squirrel, home area.	New Mexico	San Francisco	Fatal
6	1976	M	45	California ground squirrel, home area.	Kern Co.	Kern Co.	Fatal
7	1976	F	6	Chipmunk, recreational area.	Plumas Co.	San Francisco	Recovered
8	1977	F	3	Golden-mantled ground squirrel or chipmunk, recreational area.	Placer or Sierra Co.	San Diego	Fatal
9	1977	M	55	Unknown (probably a pet), work related.	Monterey Co.	Santa Clara Co.	Fatal
10	1977	F	48	California ground squirrel, recreational area.	Kern Co.	Kern Co.	Recovered
11	1978	F	57	California ground squirrel, home area.	Siskiyou Co.	Siskiyou Co.	Recovered
12	1979	M	55	California ground squirrel, home area.	Los Angeles Co.	Los Angeles Co.	Recovered
13	1979	M	15	California ground squirrel, recreational area.	Riverside Co.	Ventura Co.	Recovered

*After Nelson, B.C. 1980. Plague studies in California--The roles of various species of sylvatic rodents. Proc. Vertebrate Pest Conf. (J.P. Clark, ed.), Fresno, Calif., March 4-6, 1980. pp. 89-96.

to, preferably by a physician. Bites from bats, skunks, raccoons, coyotes, foxes, or stray dogs should always be attended to by a physician for the potential danger of rabies is high in these animals.

The frequency of rodent bites appears directly related to the number of bold rodents within the campground and the number of campers who hand-feed them.

Rattlesnakes may also be of concern in some campgrounds and posted warning notices can be helpful to call attention to the problem and prevent bites. Victims of rattlesnake bites should be taken immediately to a physician.

3. Rodent-related injury problems: Other than bites, rodent-related injury problems are relatively few and limited to stepping into ground squirrel burrows or badger holes, or tripping over soil mounds of pocket gophers or moles. Falls and associated injuries in which rodents are contributory may be rationalized or dismissed as part of the outdoor experience; however, if burrows appear in what is otherwise a well-maintained trail or bridle path, then such injuries may be viewed as the result of poor maintenance or neglect of campground facilities. Young children and the elderly are more prone to such falls. Horses and riders have been injured as the result of the horse stepping in a ground squirrel burrow.

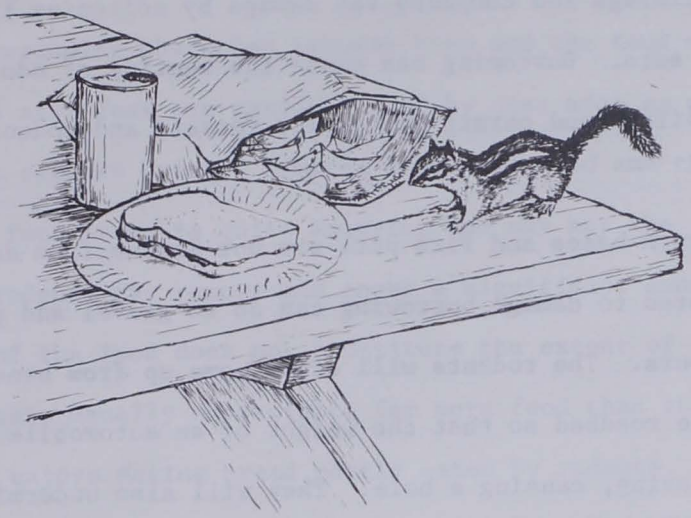
4. Structural problems: Structural damage by animals takes many forms and may not only involve rodents but birds such as swallows, woodpeckers and sapsuckers, bats, raccoons, and others. Gnawing by rodents can make structures (i.e., toilets, comfort stations, storage buildings, etc.) unsightly, remove protective finishes, permit entry of animals and insects, and, if on the roof, cause water to enter which may further damage the facility. Tree squirrels, ground squirrels, chipmunks and wood rats are often involved in gnawing on

wood or other soft building materials. Sometimes the gnawing is for the purpose of gaining entrance, presumably to food or shelter, but in some situations the gnawing is for no apparent purpose other than to keep their incisors in good shape or just for something to do.

Native rodents can cause extensive damage once they gain entrance to a building. Entrance is not always gained as a result of gnawing into the building; often they enter through existing openings (i.e., unscreened air vents or louvers, beneath doors, unsealed gaps where plumbing or electrical pipes enter building, etc.). Small mice can enter through holes or cracks no larger than 1/4 inch (0.6 cm), but chipmunks or tree squirrels require considerably larger openings. If a rodent, including a porcupine, can get its head through an opening, then entrance is imminent. Once inside rodents will gnaw woodwork, chew and shred paper, cloth, and most types of insulation materials for nests, feed on anything edible, and gnaw on plastic plumbing and electrical wires. Fires have been attributed to shorts caused by rodents gnawing on the insulation of electrical wiring. Attics , space above false ceilings, and hollow halls are favorite nesting sites, hence often have an accumulation of debris and droppings.

Porcupines frequently chew on plywood, being attracted by the bonding glue. Porcupines, and sometimes marmots, often gnaw wood, leather and other materials which have become permeated with perspiration, which contains salt. They gnaw wood toilet seats, doors, benches, and wood handles of tools; saddles, boots, and other leather goods may also be damaged. Signs, bulletin boards, and sign posts are frequently gnawed upon by porcupines, and to a lesser extent squirrels or marmots.

Burrowing by ground squirrels, pocket gophers and other rodents can cause even more serious structural damage. Toilets, comfort stations, and other



NO SMOKING
SMOKE
NAS

buildings undermined by burrows may cause slab concrete floors to crack, separate, tilt, settle or shift. Rain water and snow runoff may penetrate burrows beneath buildings and compound the damage by softening the soil on which the building sets. Burrowing can cause the venting of odors from certain types of toilets and permit access for insects and rodents to waste materials.

Picnic table bench bases and fire pits are not immune from damage, but this is minor compared to damage burrowing can do to gravel and paved campground roads and spurs. The rodents will often come up from beneath through paving or weaken the roadbed so that the weight of an automobile or camper will collapse the paving, causing a hole. They will also undermine traffic barriers and culverts.

5. Campground habitat degradation: Rodents can contribute to campground degradation through their burrowing and gnawing activities. Numerous species such as deer mice, chipmunks and ground squirrels can eliminate all natural seeding of conifer trees by consuming the seed or eating seedlings. They may also clip seedlings or girdle older trees, causing stunting or tree mortality. The burrowing of pocket gophers and ground squirrels may fill in natural or manmade drainage routes or cause excessive erosion. Road and trail washouts, stream bank deterioration and embankment earth slides have all been attributed to rodents at one time or another. Pocket gophers and moles will disfigure lawns and make them unsightly. Some of these problems are somewhat predictable with good surveillance programs, but others are not. The expense of correcting some of these problems after major damage has occurred can be substantial and thus good management practices dictate preventive measures be taken when practicable.

6. Nuisance problems: Most campers enjoy wildlife in campgrounds, but some find certain aspects of rodent behavior undesirable. High local rodent

populations will likely lead to camper annoyances, and only 1 or 2 overly bold animals may be sufficient to be a nuisance to campground users.

Food storage in campsites must be carefully considered as rodents are skillful at overcoming obstacles between them and the food supply. Plastic, cardboard, and styrofoam are easily gnawed by deer mice as well as other rodents. Most campers bring a limited amount of food and the loss or disappearance of food items is quite annoying and may mar the outdoor experience. With access, rodents may remove and cache a significant amount of food. The actual theft of the food does not constitute the extent of the damages since pillaging rodents usually contaminate far more food than they eat or carry away. Nobody enjoys eating bread partly eaten by rodents.

Rodents may gnaw and damage camping equipment. Styrofoam ice chests are easily and quickly damaged. Tent stakes, canvas, boots and clothing are frequent targets for gnawing rodents. Porcupines are especially noted for gnawing items stained with human perspiration, some furniture lacquers, and certain wood glues.

Besides damaging food and equipment, rodents may be responsible for disturbing campers with their nocturnal activities. They may climb on and enter tents, causing great alarm in some campers. Dogs may go into a frenzy of barking if chained or chase the rodent through the campground.

Certain birds may cause structural damage and be implicated in disease transmission, but generally birds and bats are more of a nuisance problem than anything else. Flickers (Colaptes spp.), both red and yellow-shafted flickers and hybrids, frequently peck holes under the eaves of restrooms and other buildings; wooden louvers are often subject to attack. Because of the large amount of guano produced, bats can be a problem when they take up residence in a building. They also may present a potential health problem, being frequently implicated as carriers of rabies. If barn swallows nest above areas

where tourists and campers frequent (e.g., where they stand to read notices or information), the birds' abundant droppings can create an undesirable situation. Once swallows have begun to nest, they cannot be disturbed without a permit from the U.S. Fish and Wildlife Service.

Exclusion by blocking, screening or netting to prevent access to the building or to the nesting site on the building is the recommended solution to bird problems.

E. Man's Role in Campground Rodent Ecology

1. Rodents and campground establishment: When man modifies a natural plant community by developing campgrounds, such alteration of habitat conditions may have profound effects on the native species of wildlife present. In general, more species of native vertebrates suffer deleteriously than profit when man alters the condition of habitats, but some adaptable species may benefit from such environmental modifications and then become more abundant than they were under the natural conditions. Many species, such as deer mice and ground squirrels, seem to thrive better when man creates open or bare-ground areas. For example, certain rodents are usually much more abundant in desert areas than in forests or well-grassed hillsides, and to increase the primary food base (vegetation) by irrigating a desert may produce more food but still eliminate all those species that are adapted to just desert conditions. Since forest lands are often cleared or partly cleared in order to build campgrounds and access roads for cars and campers, such habitat disturbances can have dramatic effects on any previously established plant and animal community. Species with limited habitat tolerance ranges are likely to be reduced or eliminated while certain opportunistic species may become predominant.

Small mammals are scarce beneath the closed canopy of mature, dense coniferous forests, where the grasses, forbs, and shrubs, their primary cover

or food sources, are shaded out. Once the trees are felled the increase in lower vegetative cover and food supply may enable certain rodent populations to grow to such a point that they become a problem.

The construction of campgrounds nearly always involves the grading of roads and campsites as well as the building of fire pits, tables and toilets. All of these activities in some way disturb the soil, and disturbed soil is favored by rodents such as pocket gophers, ground squirrels, and chipmunks. Soil disturbance by road cuts and land fills loosens the soil, making it easier for rodents to burrow or provide better drainage. Once burrows are established they rarely are abandoned; if they are, it isn't long before they are reoccupied by the same or another species.

2. Wildlife-human relationships: Human activities in campground areas are quite intense during the warmer seasons and figure as a major source of disturbance for the surrounding plant and animal communities. A management plan for campgrounds should address the influence of various human activities on rodent population dynamics.

The chipmunk and golden-mantled ground squirrel populations that reside in campgrounds are quite visible and furnish an integral part of the outdoor experience for many people; but when they are encouraged by campers to approach for food handouts they may eventually become bold enough to beg aggressively, even receiving handouts directly from human hands. Unfortunately most rodents will take advantage of any food source, whether it is offered voluntarily or not. Cardboard boxes or plastic bags of food left outside of a tent or camper are vulnerable to diurnal and nocturnal attacks by foraging rodents and, during the daytime, jays and other birds. In some places, bears, raccoons, and even coyotes can become bold enough to raid food supplies. Any unsecurely stored supplies will become easily accessible sources of supplemental

feed for these rodent and other wildlife populations, which may then benefit from such rations.

If natural forage (shrubs, herbs, insects) are abundant in campground areas, the supplementary food provided by campers will only have an incidental effect on the density of local rodent populations. Often food is not a limiting factor for a given population because some other factor is checking population, such as territoriality. Some populations are limited by the availability and abundance of plant cover, but in food-limited areas any supplemental food can contribute to the number of rodents that can survive and reproduce. In this manner, resident populations of rodents may increase both within and peripheral to campsites. The density of rodent populations in campgrounds in some instances depends upon the density of campers using the area; as the number of campers increases, so does available food, enabling denser populations of rcdents to survive in the area.

Campground visitors tend to collect quantities of slash and sticks for campfire fuel. This practice involves a certain degree of local habitat manipulation and may have an impact on rodent populations. After the start of a heavy-use season, virtually all the available slash and burnable wood may have been collected and burned, leaving the campground relatively bare. As the season progresses, campers venture further and further out into the surrounding areas in search of fuel. This slash-free maintenance of the camping area may reduce populations of some species and favor others, such as chipmunks, which may become almost totally dependent on the handouts. The effects of these habitat changes cannot be dealt with in specific detail because the habitat requirements vary, with some species having relatively narrow habitat limits, while others have a wide habitat range.

The live-trapping of rodents to take home as pets without first controlling the fleas and other ectoparasites on the animal with an appropriate insecticide

such as Sevin must be considered a hazardous practice as far as disease is concerned. Even with ectoparasite control, the practice should be discouraged as many diseases can be contracted directly from the rodent. State laws prohibit the trapping of native rodents to be sold in the pet trade.

F. Population Dynamics of Rodent Populations

Rodent populations require adequate food and shelter to thrive and these are discussed in the management plan options. Both food and shelter are factors which can, to some extent, be manipulated to regulate certain rodent populations within campgrounds.

Population dynamics vary with different rodent species. For example, meadow mice (Microtus spp.) populations tend to fluctuate dramatically every 4-7 years for reasons not fully understood. Ground squirrels and chipmunks on the other hand tend not to fluctuate much in natural environments but do substantially increase in man-disturbed environments, such as campgrounds, where their population may build up steadily over 3 or more years until relatively high populations are reached. These populations may remain high until some major natural external regulating factor such as weather, disease, or, in local situations, predation causes the population to decline, at least temporarily.

Weather, disease and predation are discussed as mortality or population-limiting factors over which man has little direct control.

1. Weather: All species survive and reproduce within a limited range of climatic conditions which depend upon the adaptations that have evolved within the species. Any extremes of temperature or precipitation may have severe effects upon the size of rodent populations. Besides the lethal effects of unfavorable weather extremes, nearly all of an animal's activities depend upon the weather, although the metabolism of warm-blooded species is not as directly dependent on the weather as poikilothermic species of amphibians

and reptiles. Life cycles are synchronized by the weather and many species avoid severe winter weather by hibernating or migrating. In addition, most animals' food supplies are affected by weather, either through rates of plant growth and fruit growth or through changes in insect populations. Drinking water and shelter provided by vegetation may depend upon weather. It is clear that variations in weather can have an impact upon the rodent-carrying capacity of some habitats.

Small mammals may face considerable cold stress and mortality when extreme cold descends in the winter and an insulating snow cover is late in developing or a thaw is followed by a freeze. When temperatures rise in the spring, rapid snowmelt can lead to flooding in areas with heavy snowfall; this situation can be an annual source of mortality in small mammal populations. Severe winter climate has been associated with changes in field populations of house mice and deer mice, especially when temperatures vary during the winter. Extreme cold may affect the food supply of small mammals by limiting the supply of vegetation; thus the effect is compounded by the lower activity levels by the small mammals in cold weather, so that less food is collected and stored, and nutritional deficiencies result.

2. Disease: The role of disease in rodent population dynamics is difficult to decipher as a single factor; the interdependence of stress and disease complicates any determination of the precise effect that pathogens have on rodent populations. But disease can severely decimate local populations during epizootics. While high population density is often associated with an epizootic, a cause-and-effect relationship does not always exist. Pathogens are spread within a population by contaminated food, vectors, or direct contact, so the spread of a disease does often depend upon population density. The impact of an epizootic also depends upon the virulence of the pathogen and the resistance of the host. Many pathogens require special

weather conditions. Overcrowding tends to be stressful, lowering the vigor of a rodent population. Stress is a complicating factor when considering disease, for it may trigger an epizootic. There is a tendency for disease to be associated with high population density, but the association is imprecise and tends to be sporadic in occurrence. Many pathogens occur at low incidence which is independent of host density.

As a single cause of death, disease may be relatively unimportant but may be instrumental in rendering an animal more vulnerable to predation or stressful weather conditions. Any mortality outside of predation is frequently due to the combined effects of starvation, weather stress, and disease.

Under certain conditions, parasitism can contribute to rodent mortality, although healthy animals can tolerate a moderately heavy parasite load. Heavy parasitism has been linked with a general decline in health of rodents during or following times of high population density.

3. Predation: The importance of predation in rodent popualtion dynamics appears quite simple upon superficial examination: one animal kills and eats another. It is often assumed that rodent populations can be limited in abundance if there are sufficient numbers of predators. This is a misleading conclusion, for predation many times operates in an incidental manner rather than as a major population depressant. Only under rare conditions can predation prove to be a significant source of mortality in rodent populations, and over time predators may maintain a higher population of their natural prey than could exist without predation.

In order to sort out the different ways that predation can act on rodent populations, they can be defined as specialists which are either nomadic, resident, or generalists.

With predators such as bobcats, weasels, and owls, rodents constitute their main prey. These predators have little ability to switch to completely nonrodent prey. Resident specialists (e.g., weasels) must increase their search movements when prey numbers are low. However, weasels can depress rodent populations dramatically when at low prey density caused by other factors, almost extirpating local populations. At high rodent population density, weasel predation has little or no effect on prey numbers; in this situation, predation acts as a culling operation and cannot check prey density. Specialists that are nomadics (e.g., owls) have been found to migrate out of areas with low population density, often without breeding.

Generalist predators are represented by foxes, martens, and badgers. These predators utilize a wide range of food items, switching in response to scarcity. Rodent populations are preyed upon when easily available; in areas with little alternate prey, predator populations may fluctuate with rodent populations. Generalist predators generally cannot depress rodent populations unless there is no alternate prey while rodents are in the decline phase of cyclic density change.

In general, predators act to harvest the surplus part of rodent populations. The failure of predators to limit rodent numbers is well documented, with a significant impact only when rodent numbers are very low. Compensation for predation losses is often seen in the form of an increased survival rate of newborn animals. If native predators leave or are removed from an area, there will usually be only a temporary increase in density of their native prey species before other regulatory factors take hold.

IV. RODENT MANAGEMENT PLAN

A. Integrated Management

Integrated management can be defined in a number of ways, but for the purpose of this volume it is a management approach or scheme that employs a combination of techniques or methods to resolve a pest rodent or rodent management problem relating to public health or facility damage. Various management alternatives are provided so that campground rangers can approach the problem in the way that appears most efficient, economical, and environmentally sound for their situation. The management of rodents in campgrounds is essentially an approach to ecosystem management because it involves more than just managing rodents.

Habitat modifications, restricting the availability of unnatural food through improved refuse management, reducing rodent populations to reduce the abundance of ectoparasite vectors of disease, facility redesigning to reduce rodent damage, and chemical control of ectoparasites implicated in rodent-borne disease are methods which are addressed in this management plan and all fall within the integrated management philosophy.

The methodology provided is principally directed towards the prevention of a buildup of excessively high rodent populations which not only increase structural or facility damage through burrowing and gnawing, but result in increased potential for outbreaks of rodent-borne diseases such as plague. The management plan is based on the premise that the plague cycle which encompasses humans most often involves fleas from infected rodents such as ground squirrels and chipmunks. It has been shown that chemical control of the flea populations alone once a plague epizootic is in progress has not provided an acceptable solution. It has also been shown that modern medicine, despite relatively effective antibiotics for the treatment of plague, has not been successful in preventing a relatively high percentage of fatalities

amongst those who contract plague and do not have it properly diagnosed quickly enough.

The management plan also assumes that doing nothing to prevent a potential plague outbreak in wild rodents, which may place humans and pets at risk, is unacceptable, and that the closing of campgrounds as a means of routinely resolving plague-risk problems is also unacceptable from an economic and resource management viewpoint.

B. Camp Sanitation and Refuse Disposal

Although considerable attention may be given to general camp sanitation and refuse disposal in the interest of public health and aesthetics, it is not always viewed in the context of how refuse disposal influences rodent populations. Most evidence suggests that one major reason rodents increase to excessively high populations within campgrounds is that there is more than a natural food supply available. This additional food comes from the deliberate feeding of rodents (and birds) by campground users and from the human food which rodents pilfer, obtain from spillage, or retrieve from improperly sealed refuse or garbage containers. No amount of effort will eliminate all these potential food sources, yet much can be done to limit the total amount available.

An adequate number of rodent-proof garbage cans or dumpsters are needed. During seasons of high camper use, spillage and the accumulation of trash placed outside of overflowing garbage cans or dumpsters may become commonplace because of infrequent pickup.

Dumpsters are often not rodent-proof because the drain holes, which are large enough for rodents to enter, are left open or unscreened. Openings greater than 1/4 inch (0.6 cm) wide will let mice enter, and a 1-inch (2.5 cm) opening is adequate for most chipmunks. Cracks, sprung lids, or gaps in dumpster lids will permit access by rodents. While rodents may not jump

from the ground to the top of a large dumpster, they may use large rocks or tree trunks as jumping-off points in order to gain access to the food. Dumpsters which are left open or without tight-fitting lids should be set at least 5 feet (1.5 m) from tall climbable or overhanging objects.

The conventional-type garbage cans must not have punctures or broken seams larger than 1/4 inch (0.6 cm), if mice are to be excluded. All cans should have snug lids. Spillage around cans should be cleaned up.

Unfortunately campers often deliberately throw surplus or waste food out for rodents or, when breaking camp, leave considerable amounts of trash including food in campground fire pits. These should be routinely checked and cleaned out.

Attempts to discourage campers from feeding rodents and birds are rarely successful even though it is pointed out that rodent bites and risk of certain diseases are substantially increased as the result of close contact. Artificial feeding of rodents is generally not in the best interests of the rodent. Even though the food provided seldom meets the nutritional needs of the animals, they frequently become dependent on such handouts.

C. Habitat Modification

Habitat modification sometimes can be very effective in reducing populations of some pest rodent species. Some of our native rodents become pests only when they become excessively numerous, and in low numbers they are considered a welcome part of the campground fauna. Most of our pest rodents have rather wide tolerances in habitat utilization; in fact, this is one factor which often contributes to their pest status.

A definition of habitat modification for the purpose of this volume will include:

1. The reduction of available food (whether from handouts, garbage, or natural sources).

2. The modification or reduction of vegetative harborage (i.e., nesting sites or burrowing sites).

3. The reduction of available free water (i.e., leaky faucets).

Habitat modifications have many limitations and are not an exacting management technique. Success is often unpredictable, as what apparently works in one area may, due to varying circumstances, not work in others. It may be very costly to carry out in view of the unpredictability of success. Rarely will habitat modifications be a one-time effort and, as with most management approaches, some continuous effort is often involved.

Rodents such as chipmunks and ground squirrels will, when possible, live close to their food source. Hence the campsites, like a magnet, will tend to attract these animals because of campers' stored food, spillage, or handouts. With the availability of food, it is not long before ground squirrels are burrowing beneath the stove, table, barrier stones, or beneath the paved camper spur, not only causing structural damage to the facilities but greatly increasing the potential for transmitting rodent-borne disease to the campers.

Through sanitation and good refuse disposal, food for rodents can be decreased substantially, but much less can be done to reduce their natural food. The removal of fallen pine cones will sometimes help reduce the food supply around the campgrounds. The cones can be scattered on the outskirts of the campground to entice the squirrels away from campsites.

Observations of rodents' feeding habits will provide clues as to possible management approaches. Certain plants are fed upon extensively while others are not. Vegetation management of brushy or herbaceous species by removing plants, by grubbing or with herbicides, may be valuable in reducing rodent numbers, although such modifications must be weighed carefully against their tradeoffs. Habitat modifications will affect many species other than just the target ones.

Low-growth shrubbery in very close proximity, say within 10 feet (3 m), to the campsite or tent pad may be desirable from the standpoint of noise-screening or seclusion, but it may also provide convenient cover for burrowing rodents close to a food source. Such habitat alterations, where possible, should provide distances greater than 15 feet (5 m) between the campsites (tent pad) and bush-shrubs, like Ceanothus spp. The pruning of the lower branches on some brushy species near campsites will open them up, making them less desirable as harborage to many rodents. This will also make it easier to detect rodent burrows in case other action such as ectoparasite control is needed.

If rocks used as traffic barriers are poorly shaped or set too shallow, they may provide excellent burrowing sites for chipmunks and ground squirrels. By properly setting rocks one-third to one-half below the soil grade, it will greatly reduce burrowing (Figure 1).

Logs and other wooden traffic barriers, if laid directly on the ground, also attract rodents by providing them good objects beneath which to burrow. If elevated off the ground by 6 inches (15 cm) or more, to prevent decay, they are less appealing as burrowing sites. The common practice of constructing

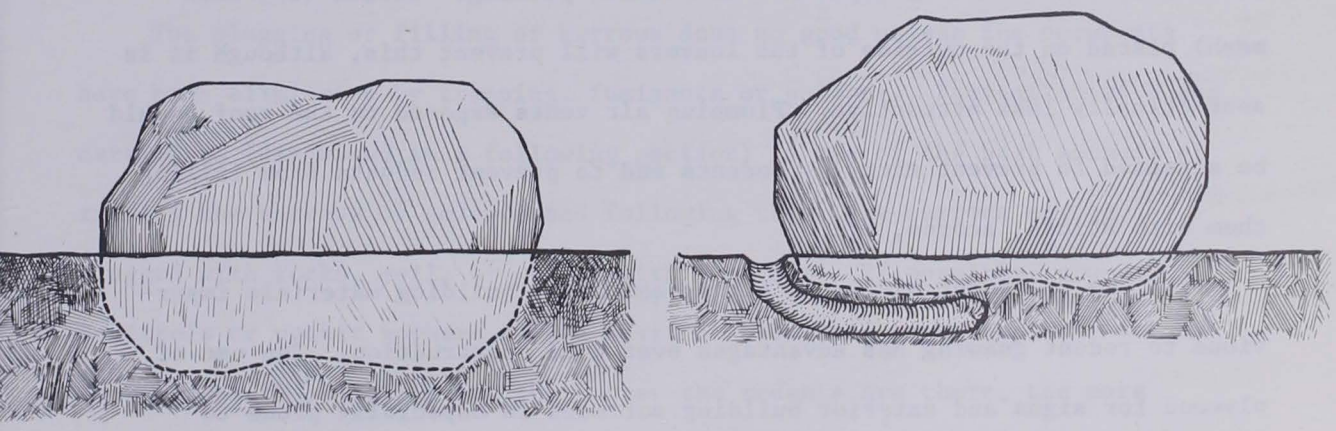


Figure 1. Barrier rocks set 1/3 to 1/2 below grade will do much to reduce burrowing. Ground squirrels and chipmunks prefer to burrow beneath shallow-set rocks and concrete slabs.

post-and-rail barriers only 2 inches (5 cm) off grade is not adequate to discourage burrowing beneath the rails.

Most rodents will survive quite well without free water, obtaining their moisture requirements from succulent foods and dew from plants. When present, however, they will often utilize water from leaky faucets and from water spillage at hydrants. It is doubtful whether water management will have much effect on native rodent populations, but with species other than field rodents, it can be quite effective.

D. Facility Design

Rodent damage to facilities is often influenced by design, construction, and the types of building materials used. In this section an attempt is made to point out or suggest where changes in construction could reduce rodent damage. The comments are not intended to resolve all of the numerous types of damage but are intended to illustrate to the architects and engineers that the majority of animal damage to future buildings could be prevented through proper design and construction. The need for architects and wildlife biologists to collaborate is obvious.

Wooden vent louvers on comfort stations are often damaged by rodent gnawing and occasionally sapsucker or flicker pecking. Screen (1/4-inch-mesh) placed on the outside of the louvers will prevent this, although it is aesthetically less attractive. Plumbing air vents exposed on the roof should be screened to prevent entry by rodents and to prevent rodents from filling them with sticks, acorns, etc.

The use of cement blocks or bricks and other building materials impervious to rodent gnawing has advantages over wood construction. The use of plywood for signs and exterior building surfaces is especially prone to porcupine damage because of their liking for the glue used in plywood. Wire

mesh and sheet metal can be used judiciously to prevent further damage once detected.

Keeping rodents from burrowing beneath concrete-slab buildings, garbage can slabs, and camp stoves is difficult. Ground squirrels and chipmunks, but not pocket gophers, always start digging right next to the foundation and when they reach the lower edge they burrow beneath the concrete slab. There are a few corrective measures which can be taken to prevent digging. A 12-inch (30 cm) wide trench can be dug along the foundation completely around the building at a depth of about 8 inches (20 cm), or to the depth of the slab, if shallower. A strip 8-10 inches (20-25 cm) wide of heavy gage wire mesh (e.g., 1/2 x 1/2-inch weldwire mesh) can be laid at the bottom of the trench butted up against the existing concrete and anchored down firmly with large exaggerated staples made from stiff wire. The trench is then backfilled with soil or gravel and the soil firmly packed. Ground squirrels starting their burrowing at the edge of the concrete will generally abandon the attempt when they strike the wire mesh. A more permanent substitute for the wire mesh would be to pour a layer of concrete several inches thick in the bottom of the trench to form an L-shaped lip which would discourage digging. The same structural changes could be successfully incorporated into new buildings.

The plugging or filling of burrows does no good unless the occupants have been eliminated by trapping, fumigants or poisons. Fumigation with gas cartridges (discussed in a following section) is one of the best methods of ridding the burrows of rodents and following this, the burrows may be plugged with rocks, soil, or sealed with concrete. If possible, ground squirrels or pocket gophers should never be permitted to become well established beneath buildings for the longer the rodents are there, the more extensive their burrows and thus the more of the subgrade that is disturbed

or excavated. If the rodents are eliminated from burrows but the burrows are not destroyed, new rodents will quickly reoccupy them.

It is very difficult to prevent high populations of squirrels from burrowing under paved roads, campground spurs, around culverts, on road-cut embankments, and in earthern dams and dikes. Generally, burrowing under these circumstances can only be curtailed by carefully monitoring these sites and controlling any burrowing animals before they become well established. Once burrows are present, new animals will move in rapidly as current residents are removed. When constructing paved roads, the shoulders should be well compacted because loose dirt invites squirrels to burrow. Pocket gopher activity must also be monitored because they burrow extensively, and squirrels, chipmunks, and other rodents are quick to take over abandoned gopher holes. Repairing holes made in roads and parking sites in campgrounds should be considered an annual maintenance job; however, the rodents living in the burrows must first be controlled.

E. Monitoring Densities of Rodent Populations

Careful surveillance is necessary to keep appraised of wildlife populations in campgrounds. To accurately assess the populations of all rodents is not practical from a management point of view; however, monitoring to obtain rough estimtes or relative densities of the population of a few key species, such as ground squirrels and chipmunks, can be achieved without great effort. All that is needed is a relative count or some other means of detecting when the density approaches the level beyond which the potential for plague or other disease epizootics is increased significantly. The best method of achieving this is to rely upon visual counts of squirrels and chipmunks and observation of their signs. Key signs are fresh burrowing activity and, especially for meadow mice in grassy sites, the presence of runways.

What is too many? No one can really say, but if squirrels have established burrows under or around 20% or more of the concrete slabs, campsites or traffic barriers, their numbers are probably exceeding desired levels. Likewise, if they have burrowed around restrooms or are causing significant damage to roadways or embankments, their populations should be reduced.

If walking or driving through the campground any time from mid-morning to early afternoon and more than 1 ground squirrel or chipmunk on the average is seen per 2 or 3 campgrounds or picnic sites, then there probably are too many. High mid-day activity is an indication of an excessive population, although young are often active then. In meadows if more than 2 or 3 squirrels per acre (5-7 per hectare) can be seen at any one time, something should be done. Remember, there will be an anticipated increase of about 3-fold in the number of ground squirrels and chipmunks following the spring littering period.

Past history of the campground has to be considered when monitoring rodents. High ground squirrel and chipmunk populations should be of concern anywhere; however, it is more important in areas where plague has been reported in the past. Rangers familiar with the campgrounds usually are aware of the relative densities of ground squirrels and chipmunks; and when their numbers are higher than any population observed previously, this suggests that the population may becoming excessively high.

Special attention should be given to campgrounds which are adjacent to grassy areas or meadows which support high populations of meadow mice (a major reservoir species of plague). Where meadow mice and ground squirrels inhabit areas in common, the potential risk of a sylvatic plague outbreak in the ground squirrels is assumed to be higher. There are too many meadow mice if by walking a transect through the meadow and parting the grass every few steps you can see distinct rodent trails once every 25 paces. Frequently

there will be pieces of cut grass and mouse droppings on the trails. The trails lead to open round burrows about the size of a 50-cent piece.

Where an epizootic of sylvatic plague is in progress or has past through a campground, it may be important to monitor the flea populations in burrows or on the surviving rodents. In accordance with current policy, vector monitoring falls under the leadership of the Department of Health Services.

Keeping a lookout for dead or dying rodents in the campground is an important part of a surveillance program. Whenever more than one sick, sluggish or dead rodent is found by campers or rangers within a week, there should be concern.

The dead rodents should be stored in plastic bags. With a plastic bag partially inverted over your hand and wrist, pick up the carcass and pull the plastic over the animal (Figure 2). Seal it tightly and place it in as cool an environment as possible (dry ice preferred). Record date, location and any miscellaneous information that may be pertinent. Then telephone your designated health authority number, especially concerning plague surveillance, if it exists. Depending on many factors, the County Health Department, State Department of Health Services, Vector Biology and Control Section, or the Plague Branch of the U.S. Center for Disease Control in Fort Collins, Colorado, will instruct you as to what to do with the carcass and whether or not they plan to intervene with a more intensive plague control or surveillance program.

The important point is to not ignore dead rodents. If the health officials are not concerned after you have reported die-offs, you have still fulfilled your responsibility. However, your observation may be the tip of the iceberg that starts an intensive survey into the occurrence of plague in your area.

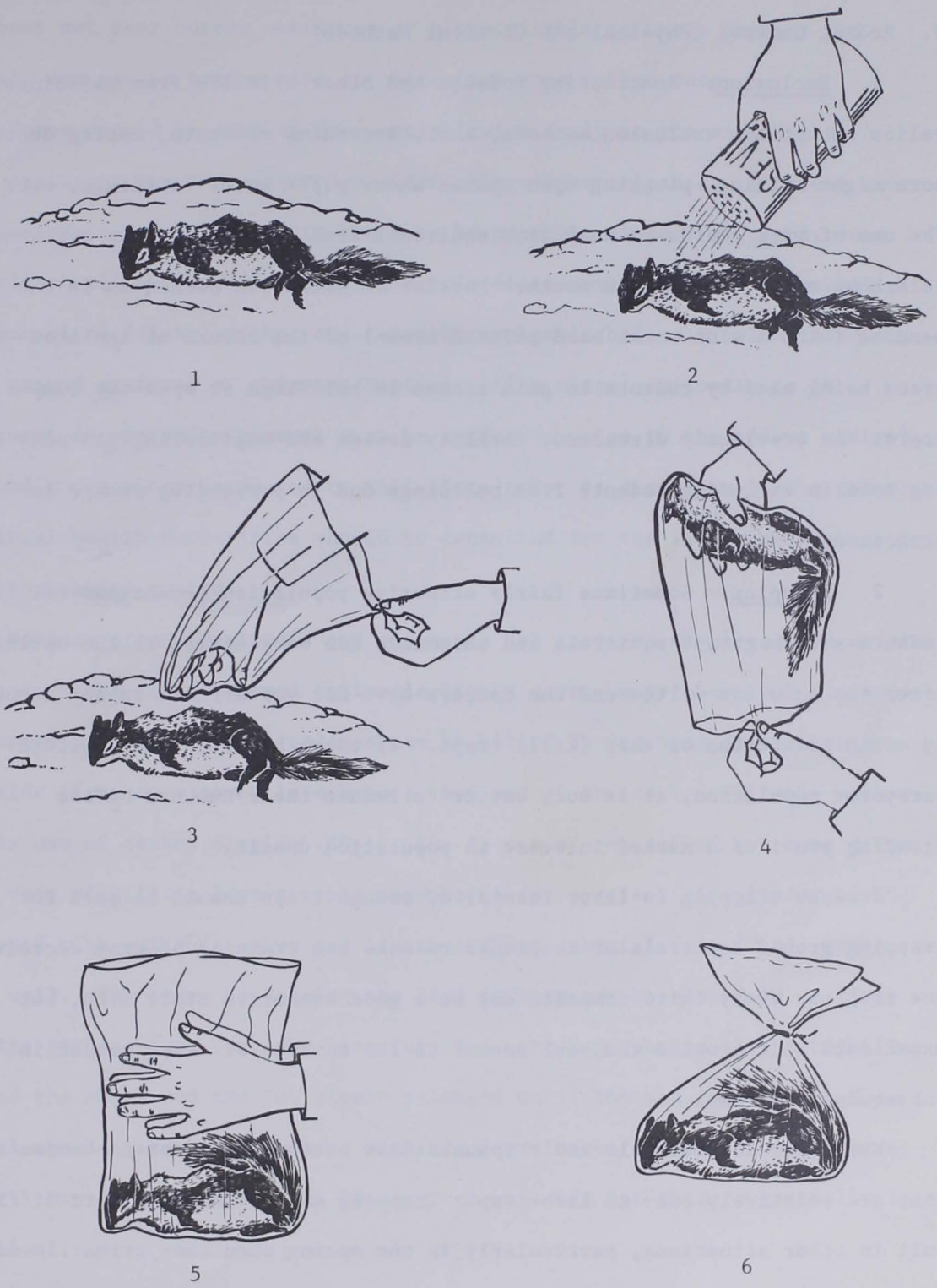


Figure 2. A safe method of picking up suspected diseased rodents involves the dusting of the carcass with carbaryl (Sevin), reaching through a plastic bag to retrieve the animal, inverting the bag over the animal without touching it and, lastly, closing and labeling the specimen.

F. Rodent Control (Physical and Chemical Methods)

1. Exclusion: Restricting rodents and other wildlife from buildings relies on various exclusion methods, i.e., screening of vents, making doors more tight fitting, plugging open spaces where pipes enter buildings, etc. The use of wire guards to keep tree squirrels from traveling along overhead telephone or power lines is another barrier or exclusion method as is the banding (with a wide metal band painted brown) of the trunks of isolated trees being used by rodents to gain access to buildings or open-top dumpsters. As previously discussed, facility design and engineering can play a big role in excluding rodents from buildings and in preventing damage to structures.

2. Trapping: Sometimes fairly effective population reductions of rodents such as ground squirrels and chipmunks can be achieved in the spring after the snow has melted and the campers have not yet arrived in any numbers, by using live traps or snap (kill) traps. If there has been a high winter carryover population, it is much better to reduce their numbers before breeding provides a marked increase in population density.

Because trapping is labor intensive, enough traps should be used for trapping ground squirrels or chipmunks to make the trapping program decisive. One trap per every third campsite may be a good number to start with, but experience will provide the best answer to the numbers of traps needed in subsequent programs.

Where ground squirrels and chipmunks have become dependent on handouts, they are relatively easy to live-trap. Trapping may be somewhat more difficult in other situations, particularly in the spring when they primarily eat green vegetation (i.e., grasses and forbs) rather than seeds.

Live traps such as the Tomahawk (Nos. 103 or 104), Havahart (Nos. 2 or 2A), or traps of similar type and size, can be used effectively. Live traps

are best set near burrow entrances or along visible pathways used by the animals and can be baited with dry breakfast-type rolled oats.

Traps should be checked frequently (twice daily at the minimum) so that nontarget species captured accidentally can be released. In areas where the squirrels or chipmunks are known to be possible disease carriers, dead animals should be handled with gloves. In disease-endemic areas, control of ectoparasites (fleas, ticks, etc.) may be advisable before or simultaneously with ground squirrel or chipmunk control. If a plague epizootic is in progress, ectoparasite control must be conducted prior to any rodent control. Trapped rodents can be dusted to kill fleas prior to disposing of the rodents. The local health authorities should be consulted for the latest recommendations on ectoparasite control.

Because ground squirrels and chipmunks are carriers of plague and several other diseases, live-trapped squirrels should never be released but disposed of humanely. Live-trapped rodents can be killed by drowning or with carbon monoxide (from an automobile exhaust), but one of the most acceptable methods is the use of carbon dioxide (CO_2). CO_2 is one of the safest and most effective ways of killing live-trapped rodents of any species. A cylinder of CO_2 equipped with suitable valve and length of hose (about 6 feet [2 m]) works very well. The traps containing the live rodents can be placed in a large plastic garbage-type bag, the hose inserted, the bag opening closed tightly around the hose, and the CO_2 slowly released until the bag is filled. The animal should become unconscious within a few minutes and die shortly thereafter. Dry ice also gives off CO_2 and can be used, but this is generally less practical.

Modified California-44 pocket gopher and small Conibear (No. 110) traps have been used effectively for the California ground squirrel. Some of the

smaller ground squirrels and chipmunks can be taken with ordinary wooden rat traps. Baits of cereals (rolled oats mixed with peanut butter), nut meats, raisins, prunes, or slices of orange are quite effective but should be tied tightly to the trigger to prevent theft without tripping the trap. All of these traps kill the squirrels instantly. Keep in mind that kill traps used above ground are not totally selective and nontarget animals may occasionally be caught.

For pocket gophers and moles trapping is an effective control measure, especially if only a few dozen animals are involved. There is almost no hazard to nontarget species because the traps are set in the burrows below ground. For moles, gripping-type kill traps are probably best suited for campground use. These include the scissors-jaw, choker-loop, and diamond-jaw type traps. The Macabee-type and box traps are the most common traps used for pocket gopher control.

Dead rodents can be disposed of through the normal garbage pickup system, but all rodent carcasses should be placed in tightly sealed plastic bags prior to disposal.

3. Acute (single-dose) Rodenticides): Anticoagulant (multiple-dose) toxicants are generally safer and about as effective as the acute (single-dose, one-shot) poisons for rodent control. There are times, however, when the quick-acting acute poisons are preferred, such as when the disease hazard is high and an area requires a rapid reduction in the rodent population with a minimum of labor and expense. Sometimes the slow-acting, multiple-feeding anticoagulants may not be practical because it may not be possible to maintain the needed bait stations throughout the campground. Rodenticides are selected on the basis of their safeness and efficacy for a specific species and depending upon the situation. For example, the acute rodenticide strychnine is the best rodenticide for both pocket gophers and porcupines, and zinc phosphide is

the preferred rodenticide for the control of meadow mice. The rodenticide selected must be registered for the intended use.

If it appears that an acute rodenticide is needed, you should contact your Forest Service authority on animal damage control and your County Agricultural Commissioner for current control recommendations. In California most acute rodenticides require a permit for purchase and use. These are issued by the County Agricultural Commissioner.

Acute rodenticides (Table 3) are very useful for achieving a quick knock-down of an initial rodent population. The same acute toxicant should not be used more than twice a year, preferably only once. When an acute toxicant is used repeatedly in the same locality, a bait and/or poison-shy population of rodents may develop. Hence it is best to change the bait and poison periodically.

4. Chronic (multiple-dose) rodenticides: The effects of anticoagulant rodenticides are cumulative, and the materials must be consumed over a number of days to produce death. That is why they are considered relatively safe for man and other nontarget animals. Other values are that they are quite readily accepted by rodents and rodents rarely develop a shyness to anti-coagulant baits of good quality. Anticoagulants act by interfering with blood clotting, with death resulting from internal bleeding. The onset of symptoms is relatively slow, and when ingestion is not intentional, there is time for administering vitamin K_1, an effective antidote, or giving whole-blood trans-fusions. Anticoagulants can be used in dry baits, and their sodium or other soluble salts can be used in water baits. Water baits are only recommended for indoor use. For greatest effect, rodents should feed on the treated bait each day. The intervals between feedings should never exceed 2 days at most. Depending upon the anticoagulant and the amount consumed, the first deaths in rodents, depending on the species, should be apparent about the

Table 3. Acute and chronic (anticoagulant) rodenticides listed by commercial chemical names.

	Common name*	Chemical name
Acute Rodenticides		
	Zinc phosphide	Zinc phosphide (Zn_3P_2)
	1080	Sodium fluoroacetate or sodium monofluoroacetate
	Strychnine	Strychnine alkaloid or strychnine sulfate
Chronic (anticoagulant) Rodenticides		
	Brodifacoum	3-[3-(4'-bromo[1,1'-biphenyl]-4-yl)-1,2,3,4,-tetrahydro-1-naphtalenyl]-4-hydroxy-2H-1-benzopyran-2-one
	Bromadiolone	3-[3-(4-bromo[1,1'-biphenyl]-4-yl)-3-hydroxy-1-phenylpropyl]-4-hydroxy-2H-1-benzopyran-2-one
	Chlorophacinone	2-[(p-chlorophenyl) phenylacetyl]-1,3-indandione
	Diphacinone	2-diphenylacetyl-1,3-indandione
	Fumarin	3-(a-acetonylfurfuryl)-4-hydroxycoumarin
	Pival	2-pivalyl-1,3-indandione
	Warfarin	3-(a-acetonylbenzyl)-4-hydroxycoumarin

*Trade names are given where no established generic names are available.

fourth day after first exposure. When anticoagulants are used, keep bait exposed continuously for at least 2 weeks, or until all feeding ceases.

Of the anticoagulants shown in Table 3, all require multiple feedings over several days to be lethal except for bromadiolone and brodifacoum which are referred to as second-generation anticoagulants that are frequently lethal to some rodent species after one feeding, although death will be delayed by several days. Warfarin, Fumarin® and Pival® are the slowest acting, requiring the greatest number of repeated feedings, thus the safest anticoagulants. Diphacinone and chlorophacinone are intermediate in the number of feedings required. Some potential primary and secondary hazards exist to nontarget species regardless of whether acute or anticoagulant rodenticides are used, but these are very minimal if used in accordance with label instructions.

Anticoagulant baits are usually offered to rodents in bait boxes which protect baits from the weather and restrict accessibility of the bait to rodents, thus providing an excellent safeguard to people, pets, birds, and other animals. A very effective way to reduce rodent population densities is by using about 1 bait box for every 4 or 5 campsites early in the spring for a few weeks. The bait boxes can all be removed before many or any campers arrive. Some examples of different types of bait boxes are shown in Figure 3.

5. Fumigants: Some fumigants (toxic gases) are very effective for controlling burrowing rodents such as various species of ground squirrels. Their use is limited to times of the year when the animals are not hibernating or estivating, for during such periods the squirrels barricade themselves behind an earth plug in the burrow to exclude the outside elements, also excluding penetration by the fumigants. The best time of year to use fumigants is in the spring after the ground squirrels have emerged from breeding and

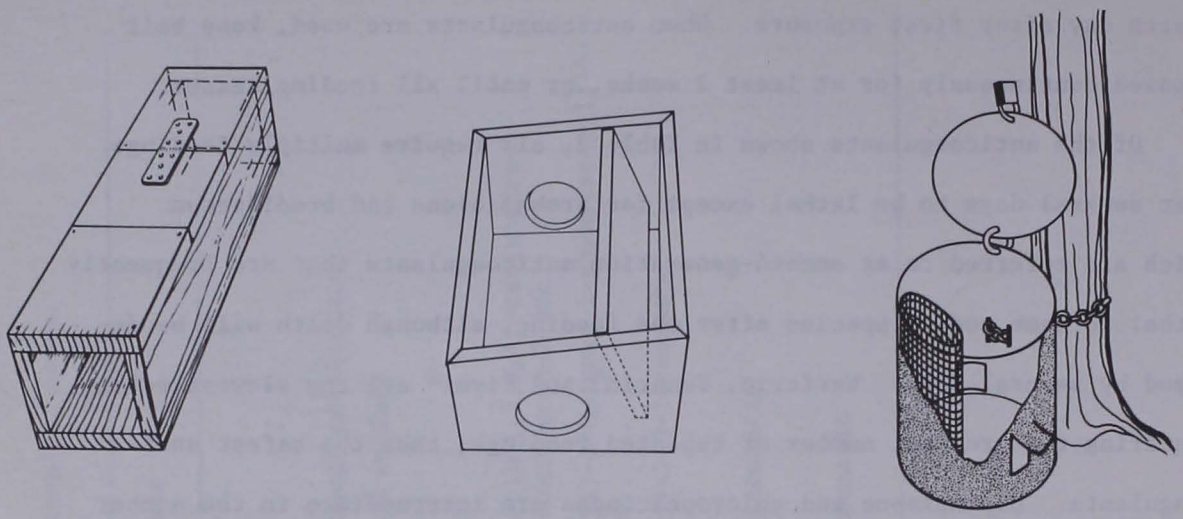


Figure 3. Examples of 3 types of bait boxes or stations. They vary from simple tunnel-type boxes (left) to boxes with bait-hopper arrangements (center, lid not shown). Five-gallon cans also can be converted to bait stations by adding a wire-mesh hopper and providing 2 small openings about 3 inches (7.6 cm) in diameter.

before the young are born. Also, this can usually be done in the spring before any or many campers have arrived. All fumigants are most effective when the soil is damp, for moisture in the soil prevents the gas from escaping the burrow system. Fumigants are not recommended for those species of animals that construct extensive burrow systems with frequent internal soil plugs such as pocket gophers and moles. Fumigants obviously are of no value in controlling campground rodents which do not construct or live in burrows.

Carbon bisulfide, methyl bromide, and gas cartridges have all been used successfully. Calcium cyanide requires substantial soil moisture to rapidly liberate the gas, and for that reason it is not always highly effective for ground squirrels. Carbon bisulfide, methyl bromide, and calcium cyanide are all classified as restricted materials and require a permit from the County Agricultural Commissioner before they can be used. Fumigants should not be

used if there is danger that the toxic fumes will escape into buildings. Since carbon bisulfide and methyl bromide are phytotoxic, they should not be used where burrows extend beneath trees or other valuable plants. Carbon bisulfide is also highly inflammable. Methyl bromide is highly toxic but has the advantage of being the most lethal to fleas which may infest the burrow. Both carbon bisulfide and methyl bromide are potentially quite hazardous to the user and should be applied only by those experienced in handling them. Label directions for use should be followed closely, regardless of the fumigant.

Gas cartridges, sometimes referred to as "woodchuck" or "smoke" bombs, are a mixture of ingredients formed in a small cylinder-shaped cartridge with a fuse inserted. When ignited and inserted into a burrow, it gives off toxic fumes and smoke. To confine these suffocating and toxic gases to the burrows, close all entrances with sod or soil packed tightly.

Of the available and effective fumigants, gas cartridges are the simplest to use and can be used by anyone having no previous experience with fumigants. There is a slight fire hazard associated with the gas cartridges so care should be taken if used around dry and combustible material.

Gas cartridges are available from several manufacturers and from the U.S. Fish and Wildlife Service through the Department of Interior's supply depot in Pocatello, Idaho (ordered through the State Supervisor, Federal Building, Room E-2717, 2800 Cottage Way, Sacramento, CA 95825). Some agricultural commissioners also have USFS gas cartridges available for purchase.

G. Biological Control

Biological control as commonly defined can be viewed as population reduction that involves biological means such as the use of pathogens (diseases) or predators. Biological control has been effectively used to control certain insect and weed pests but to date has had little success in vertebrate pest control for a variety of reasons. Attempts at biological

control in the past have resulted in disastrous results causing human fatalities and catastrophic losses of nontarget wildlife. There are currently only a few examples of biological control that have been successful in controlling specific vertebrate pest species.

1. Predation: It has been a long-standing intuitive but incorrect concept in biology that vertebrate predators exert strong control over vertebrate prey densities, maintaining them at low levels. The implication of this mistaken view is that removal of the predator will result in a long-term increase in the prey population and that, conversely, one might be able to control a pest species by stimulating its predators or by introducing new ones. However, much evidence exists to refute this hypothesis. It appears that under natural conditions predators act to maintain a higher density of their vertebrate prey than would otherwise prevail over long time periods and may increase the vigor and reproductive success of the prey. In a natural vertebrate predator-prey relationship, the density of the prey limits the size of the predator population, but predators do not destroy or greatly curtail the prey population. If the predators are artificially removed, there is a temporary increase of the natural prey species, but in time the prey populations decline below the higher carrying capacity perpetuated by predators. Evidence abounds in the literature of the inefficacy of introduced predators in controlling vertebrate pests.

Numerous examples exist of predators being introduced to control vertebrate pests and, with few exceptions, not resolving the original pest problem but almost always becoming pests themselves by preying on desirable vertebrates. One of the classic examples is the mongoose (Herpestes auropunctatus) introduced into Hawaii to control rats and now considered to be a factor in the decline of the rare nene or Hawaiian goose (Branta sandvicensis). The mongoose

may be largely responsible also for the extermination of the Manx shearwater (Puffinus puffinus) in the Hawaiian Islands. Too often it is forgotten that most of our major pest vertebrates are very successful animals, having very high reproductive rates, wide environmental tolerances, or high adaptability. These are part of the makeup contributing to their pest status; but more important, these same characteristics make their control by biological means as known today of questionable value.

2. Diseases (epizootics): The introduction or stimulation of epizootics, i.e., virulent diseases, as a type of biological control has had a long history. The use of bacterial disease such as Salmonella dates back to the 19th Century. The major drawbacks to such an approach are that the diseases may be transmissible to man, domestic or wild animals other than the intended target species. Resistance may develop in the pest species after initial high mortality rates. This limits the utility of natural rodent disease organisms, of which there are many in California. Past attempts at using Salmonella bacteria in rodent control not only failed to give good control but resulted in some human deaths.

The myxoma virus (the only really effective man-introduced epizootic) was used on the European rabbit in Australia. Although the results were spectacular at first, the virulence of the virus is now greatly reduced and in some areas more virulent strains must be reintroduced periodically.

The introduction of diseases or predators is often suggested by the uninformed as the best and most natural approach to reducing the density of vertebrate pest species. Past history and present knowledge indicate that the biological implications and potential environmental catastrophes associated with these approaches are far-reaching and generally irreversible once initiated. Any use of biological control of vertebrate pests should be studied in great depth and reviewed most critically before implementation.

H. Experimental Control Methods

1. Chemosterilants: Chemosterilants are chemical antifertility agents, designed to interfere with reproduction in some manner. There are many different physiological mechanisms by which such interference can occur, but the ultimate objective is to induce temporary or permanent sterility or otherwise reduce the fecundity of a target species. There are no chemosterilants currently registered for rodent control. Control through reproductive inhibition is also likely to be more acceptable to some segments of the public than existing lethal agents and devices. It should be noted that chemosterilants will never replace traps or toxic rodenticides entirely, as there are many situations where rodents cannot be tolerated even if sterile. Sterile rodents will still feed on crops, contaminate foodstuffs, transmit diseases, and cause structural damage. The main value of chemosterilants would be to suppress the reproductive rate of a rodent population after some conventional control method had been used to reduce the density to a tolerable level.

A unique advantage of chemosterilants over lethal aspects is in controlling rodent populations (i.e., ground squirrels and chipmunks) that are implicated in endemic sylvatic plague or other diseases. In this situation chemosterilants could prevent populations from building up beyond a desired level in campgrounds. It would not simultaneously destroy large numbers of rodents. Gradual mortality of sterile carriers would not cause a sudden massive liberation of their ectoparasites, as would a toxicant control program, where such a release increases the risk that the vectors will spread rodent-borne diseases, thus necessitating additional treatments for the control of insect ectoparasites.

2. Genetic control: Pest control may also be achieved through the direct manipulation of the gene pool within a population of rodents. This is done either by the introduction of a different breeding stock or by the use

of mutagenic compounds that induce genetic alterations. The result is that the animals become less successful in the environment and are more susceptible to destruction by natural regulatory factors or by some self-destructive mechanism or behavior. Alternatively, their behavior may be altered by genetic control such that they are less of a pest to mankind. In recent years there has been some experiments conducted with the genetic control of feral populations of Norway rats, but no work to date has been directed towards native rodent species.

A major attraction of this type of control is its high degree of selectivity, affecting only a single species and, within that species, only the population whose genetic makeup has been altered. There are virtually infinite possibilities by which the life history of a pest species may be sabotaged by genetic control. However, the technique is very difficult and costly to implement in practice. There is considerable difficulty in establishing and maintaining lethal or disadvantageous genes in a population, as they are continually being selected against. What is needed are genes that are desirable from a pest control standpoint and that also have a selective advantage to that species.

Unless some compound capable of inducing desired mutations is developed, genetic control will always be an adjunct to more traditional forms of control. The introduction of large numbers of additional animals into a pest population is generally undesirable as a vertebrate control procedure, except in the instance where such animals were harmless or less of a pest than the original population. Much further research into population genetics and genetic engineering is necessary before this type of biocontrol can be considered feasible.

3. Pheromones: These are chemical substances secreted by an animal that elicit a behavior or physiological response in other individuals of the same species. Pheromones may be of two types: releaser (signal) pheromones which cause immediate behavioral responses or priming pheromones which induce a gradual physiological change, usually acting through a hormonal (endocrine) pathway. As a direct method of pest control, pheromones have been successful in varying degrees when used on some insects. Vertebrate pests, however, are far more complex in their behavior and do not exhibit the automatic fixed reactions common to invertebrates exposed to pheromones. Possibly some day pheromones will be used with the more conventional control techniques to achieve more selective and effective rodent control. Theoretically the possibilities are great, but the complexity of mammalian chemical communication necessitates years of additional research.

I. Ectoparasite Control

Several types of ectoparasites may be implicated as vectors of diseases associated with campgrounds. Other than fleas, which are the subject of this discussion, the other ectoparasites only rarely necessitate control. Where ectoparasites other than fleas become a problem, consult with your local county health department or with the State Department of Health Services.

The Department of Health Services is the lead agency in making recommendations for flea control relative to plague; however, some general information on flea control will help put rodent management in proper perspective.

A few years ago there were a number of effective insecticides available for use in flea control. These included DDT, dieldrin, aldrin, malathion, and several others. Currently, carbaryl (Sevin) (5% active ingredient) is registered for use in campground situations. Unfortunately, carbaryl has not always given adequate flea control in all situations. DDT remains the most

effective insecticide for flea control but it is not available for routine use. DDT can, however, be used when the Department of Health Services indicates that a health emergency exists. A substantial amount of red tape is involved when DDT is used, and a comprehensive use report must be filed.

Flea control can be accomplished by several application methods. In the past, area dusting with ground dusters and by aerial application was used with success. However, at that time the more residual types of insecticides could be routinely used. Currently, area dusting has been replaced with dusting of ground squirrel and chipmunk burrows and wood rat nests. Although effective, this approach is labor intensive. Burrow dusting must be thorough to be effective, and this is not always easily achieved because many of the burrows are difficult to locate in some rocky or brushy habitats and some dusting crews are not the most conscientious in carrying out the work. Another approach to flea control is the use of bait stations containing an insecticide. These are enclosed stations with two rodent-size openings. The stations are baited with clean (nontoxic) grain to attract the rodents and an insecticide dust, such as carbaryl, is placed on the floor of the station. When rodents enter the stations to feed, they pick up the insecticide on their fur. This not only controls the fleas on the animal, but sufficient amounts of insecticide are transferred to the burrow, also controlling fleas there. One shortcoming of this method involves territoriality of some ground squirrels, which may keep some rodents away from stations, but additional stations will help resolve this problem. Where rodent control is also needed the insecticide bait stations can be used for dual purposes, exposing insecticides and an anticoagulant rodent bait simultaneously. Acute rodenticides should not be used jointly with the insecticide because they act too rapidly, killing the rodents before effective flea control can be

achieved. When an epizootic is in progress, ectoparasite control should be conducted prior to controlling rodents except where insecticides are used in anticoagulant bait stations. Failure to do this may result in transfer of infected fleas from dying rodents to man or his pets. Flea control need not precede routine rodent control where no epizootic is evident.

Only insecticides registered for pets should be used to control fleas on cats or dogs. Apply as directed by label instructions.

Repellents, such as DEET (diethyl toluamide) are somewhat useful in repelling fleas from clothing and thus provide some protection from being bitten. Repellents at best are only partially effective, however.

J. Management Strategies

The selection of various management options, and assembling them into some organized plan, is referred to as management strategies. Management strategies are really an implementation plan for achieving a management goal, in this case a reduction in potential plague or other rodent-borne disease risks and/or a reduction in rodent-caused facility damage. Table 4 provides a ready reference to the important rodent management options. In no instance is the total elimination or eradication, even locally, of a rodent species suggested. On the contrary, every option provided can be carried out to achieve the desired goals without jeopardizing the entire population.

In plague-related problems the emphasis is either on ectoparasite (flea) control or on the control of ground squirrels or chipmunks (the animals most often implicated in transmission of the disease). Few controls are aimed at the plague-reservoir species, such as meadow mice or deer mice, since presently there is no direct evidence that this approach would be effective, yet it cannot be totally discounted from a theoretical point of view.

Table 4. Species of California rodents implicated in campground diseases and damaged facilities, and the various types of management and control methods that can be used to resolve the problems.

	Sanitation	Habitat modification	Rodent-proofing	Trapping	Toxic baits	Fumigants
California ground squirrels	X	X	X	X	X	X
Golden-mantled ground squirrels	X	X	X	X	X	X
Chipmunks	X	X	X	X	-	X
Western gray squirrels	-	-	X	X	-	-
Deer mice	-	X	X	-	X	-
Wood rats	-	X	X	X	X	-
Porcupines	-	-	X	X	X	-
Meadow mice	-	X	-	-	X	-
Pocket gophers	-	-	-	X	X	-
Moles*	-	-	-	X	X	-

*Moles are not rodents but are included because their burrowing activities and types of damage often resemble that of pocket gophers.

A variety of information and options have been given and these can be integrated in many ways, depending on the situation and desired immediate and long-term goals. Any rodent management plan needs some degree of flexibility because of changing conditions, hence management strategies will change from season-to-season or from year-to-year as the situation demands. Although not indicated, monitoring or surveillance is an integral part of all management plans. No action, of course, is always an option, but it is not included in the strategy examples provided.

The following are provided as possible strategies under different circumstances:

1. Strategies prior to a plague outbreak: Examples of several different types of management strategies that can be followed are given in a condensed form:

    a. Flea control only by dusting rodent burrows.

    b. Flea control only by the bait-box method.

    c. Ground squirrel control by trapping and possible selective fumigation and improved sanitation.

    d. Ground squirrel control by trapping and limited habitat modification.

2. Strategies following a sylvatic plague outbreak: Different management strategies that might be selected immediately following a plague outbreak include:

    a. Flea control by dusting burrows and/or by the bait-box method and campground closure.

    b. Flea control by dusting burrows, posting of plague warning signs, and restricting pets from campgrounds.

c. Flea control by dusting burrows and rodent control with anticoagulant bait in conjunction with ectoparasite control by the bait-box method.

3. Strategies for preventing facility damage: Examples of different types of management strategies. These may be directed at offending animals or be intended to reduce the population of offending rodent species to acceptable levels, i.e., below that number which results in excessive damage.

a. Trapping of offending animals, make some changes in facility design, and the fumigation of all burrows in campsites and beneath paving.

b. Ground squirrel control by anticoagulant baits, improved sanitation, and habitat modification.

c. Exclusion or construction of barriers to prevent rodent entry into buildings, fumigate all burrows prior to making repairs to roads, pathways, or facilities which require filling or otherwise destroying the burrow openings.

d. Improved sanitation, limited habitat modification, with trapping of rodents as a last resort.

V. PUBLIC AWARENESS

A. Suggestions for Minimizing Risks from Plague

Precautionary measures for campers in high-risk plague areas or in campgrounds where plague has been identified the previous year are as follows:

1. Do not handle sick or dead rodents. Report sightings of dead or diseased animals to park rangers or county health authorities.

2. Do not place tents or sleeping bags near entrances to rodent burrows as fleas may seek any warm-blooded host. If possible, avoid sleeping directly on the ground.

3. Use insect (flea) repellents especially on bare arms and legs. Pants and long-sleeved shirts offer some protection against fleas and are preferred over clothing which exposes bare arms and legs.

4. Leave pets at home. Infected fleas may move from squirrels to pets to man. If this is impossible, keep pets on leashes and treat them periodically with flea powders. Flea collars generally do not work fast enough to offer adequate protection to the pet.

5. Do not feed rodents. (Rarely will this suggestion be adhered to.)

6. Be alert for symptoms of plague: fever, nausea, headache, and/or swelling of lymph nodes in the groin or armpit area. The presence of such symptoms along with the fact that you have been in a plague-infested area, have been around dogs or cats possibly exposed to plague-infected animals, or have any other reason to suspect plague, indicates you should see a physician immediately. Inform him you have been in a potential plague area.

B. Suggestions for Minimizing Plague Hazard to Pets

Plague also presents a potential hazard to pets. Dogs or cats may play with, mouth, or feed on sick or dying infected rodents and thus contract plague directly from the diseased animal. For this reason it is important to keep pets on a leash or otherwise confined. Also, infected fleas whose host

has died may find a readily available home on pets, and infect the pets when feeding upon them.

There are always the hazards of plague-infected fleas being transported from the campground to the camper's home via the fur of pets.

The following suggestions are provided for those pet owners who value their pets as well as their own and their families' health.

1. If possible, avoid taking pets into campgrounds where plague has been identified in the past. This is particularly important if a high rodent population exists in the campground.

2. If a pet cannot be left at home, it should be kept confined in the camper or trailer and only taken out on a leash.

3. If walking the dog, don't permit the animal to touch or feed on rodent carcasses it may find.

4. Dust pets with flea powder prior to walking and again prior to leaving the campground. Flea collars do not act rapidly enough to offer the pet much protection from initial bites or in preventing the pet from transporting a flea to a tent or camper.

5. Sick pets should be taken to a veterinarian, who should be informed that the pet has been in a plague area.

C. Public Education on Disease Risks

The education of campers, backpackers, and hikers as to the disease hazards associated with rodents is probably one of the best methods of protecting the public from excessive and unnecessary disease risks associated with rodents or the out-of-doors in general.

In the past, diseases like plague have been played down in importance by some public health agencies and health officials because of the concern for alarming the public. The wisdom of this philosophy now appears questionable, for it leads to a laxity in the public's willingness to take reasonable precautions to protect themselves. It has led to the belief that

rodent-borne diseases are of little hazard, and hence when some significant action must be taken in the public's behalf against the involved wildlife or their ectoparasites, public support is often lacking.

It seems to us that the public should rightfully know of existing disease hazards and the severity of some of the potential diseases. The health risks associated with the use of either private or publicly owned campground or recreational facilities should be common knowledge.

The posting of plague-warning signs in campgrounds and media news reports have served to make the public aware of the plague problems. This is good, but consideration should be given to making an even greater effort to educate the public on potential disease problems. While the Forest Service may not be in a position to directly undertake a greater role in such education, they might pursue or solicit the cooperation of those who are involved in some way in health education, such as the cooperative extension service, city, county, or state health departments, county or state departments of agriculture, and the U.S. Department of Health and Human Services.

A variety of leaflets, pamphlets, slide series, and movies relative to rodent-borne diseases is available from various sources. Consideration should be given to fully utilizing them. These might also be used to educate or train Forest Service personnel, particularly new or seasonal employees.

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